metal treatment

Vol. 26 : No. 165 JUNE, 1959 Price 2/6

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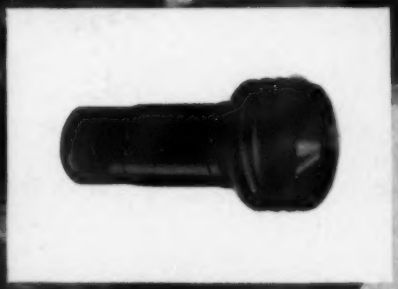

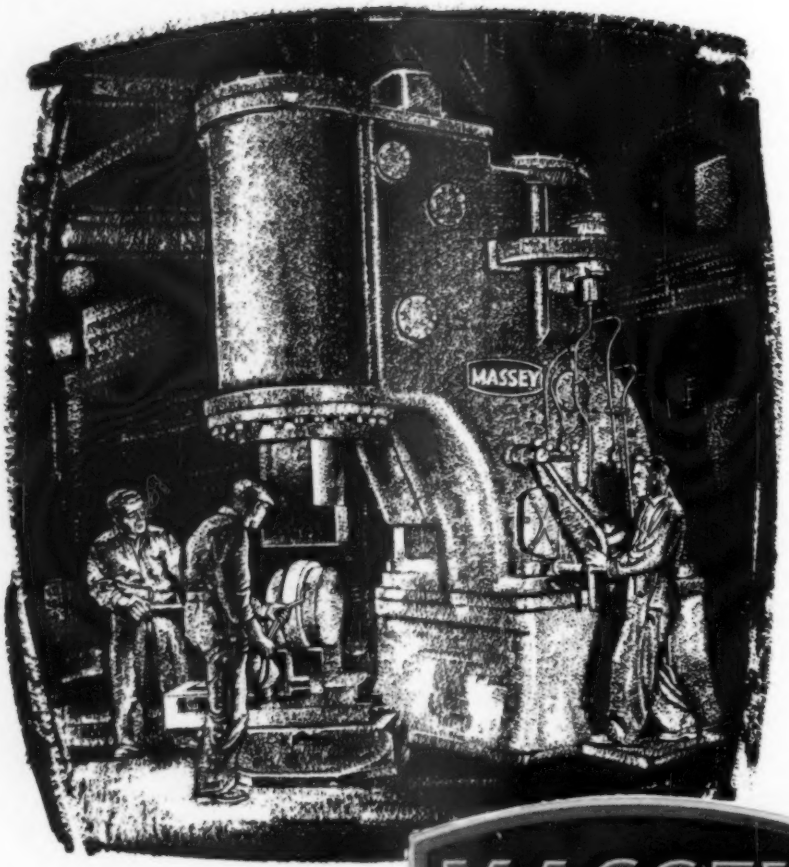

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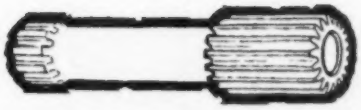

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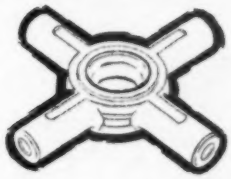

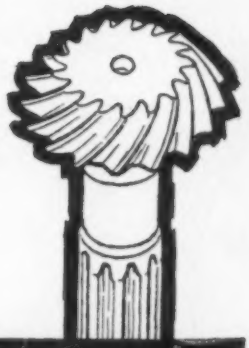

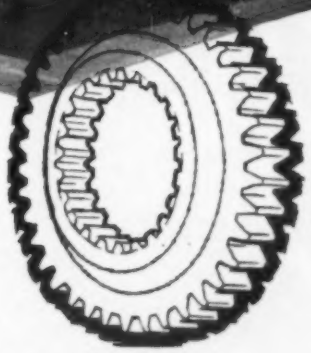

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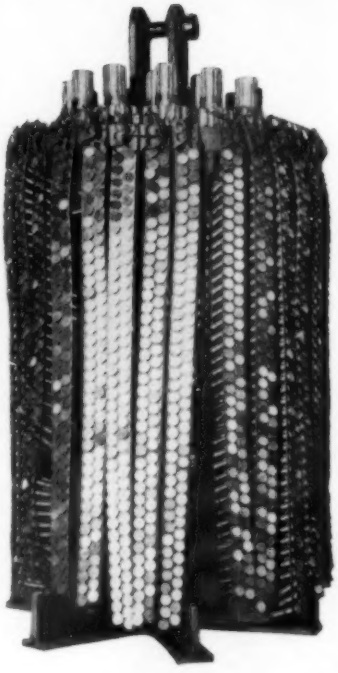

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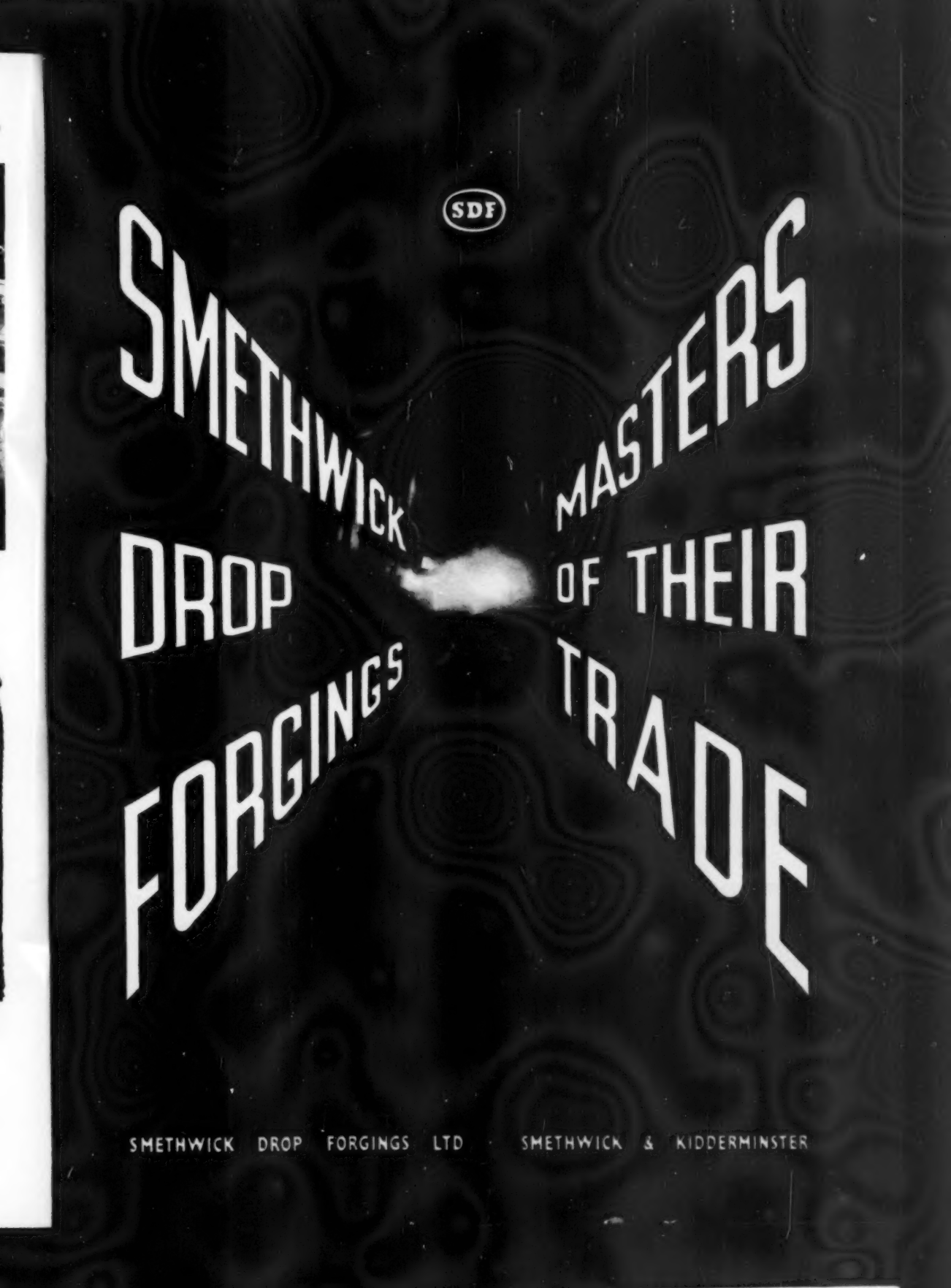
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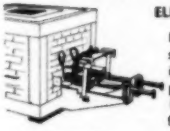

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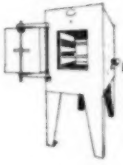

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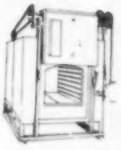

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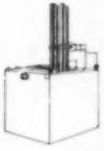

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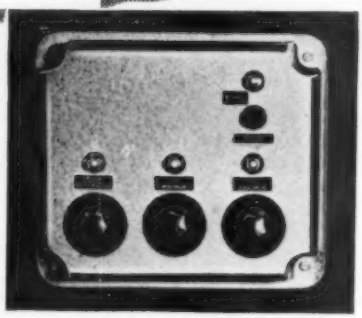

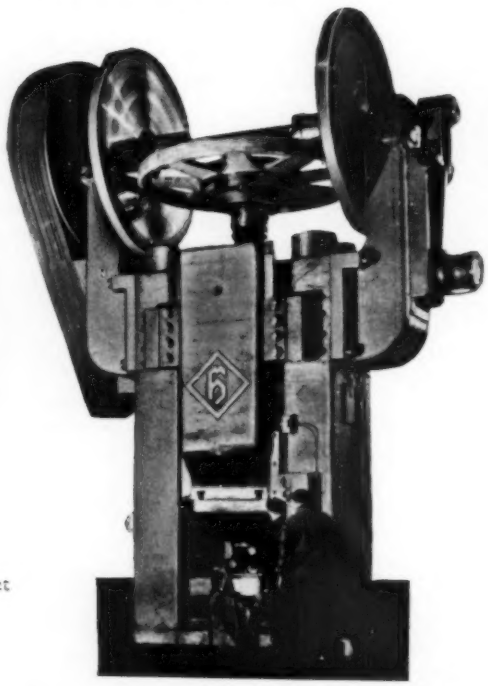

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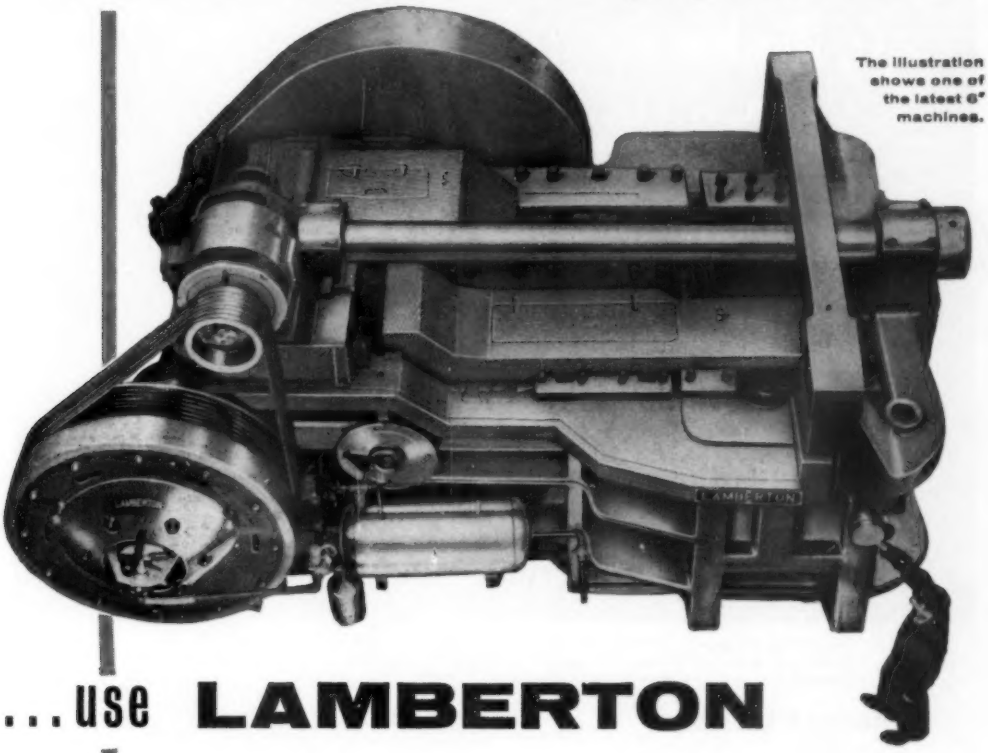

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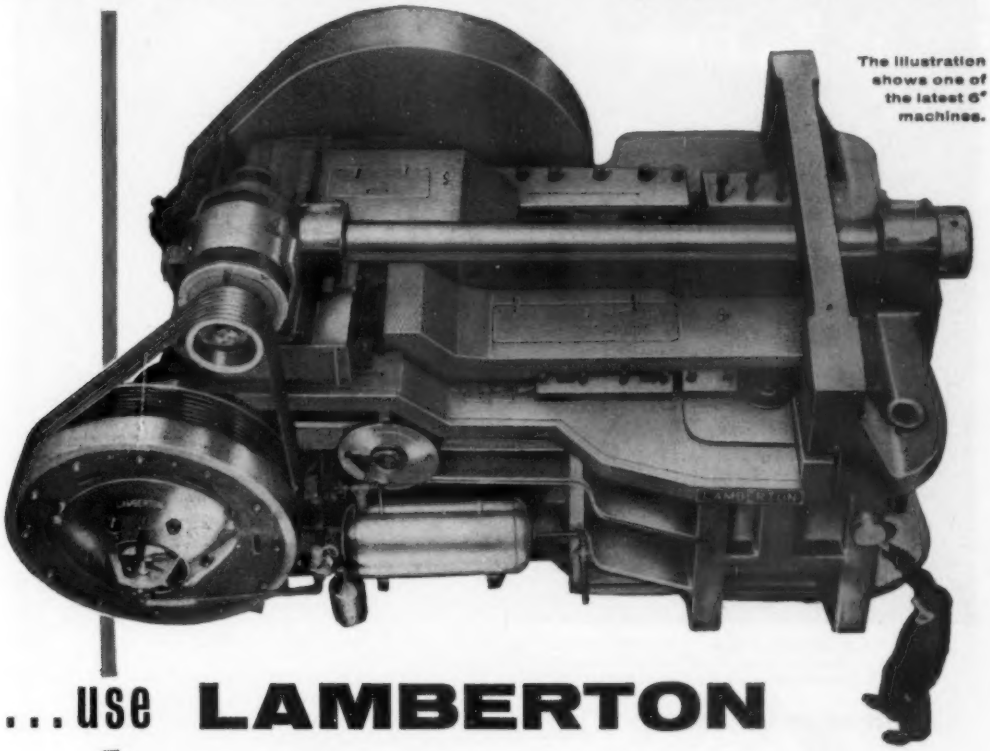

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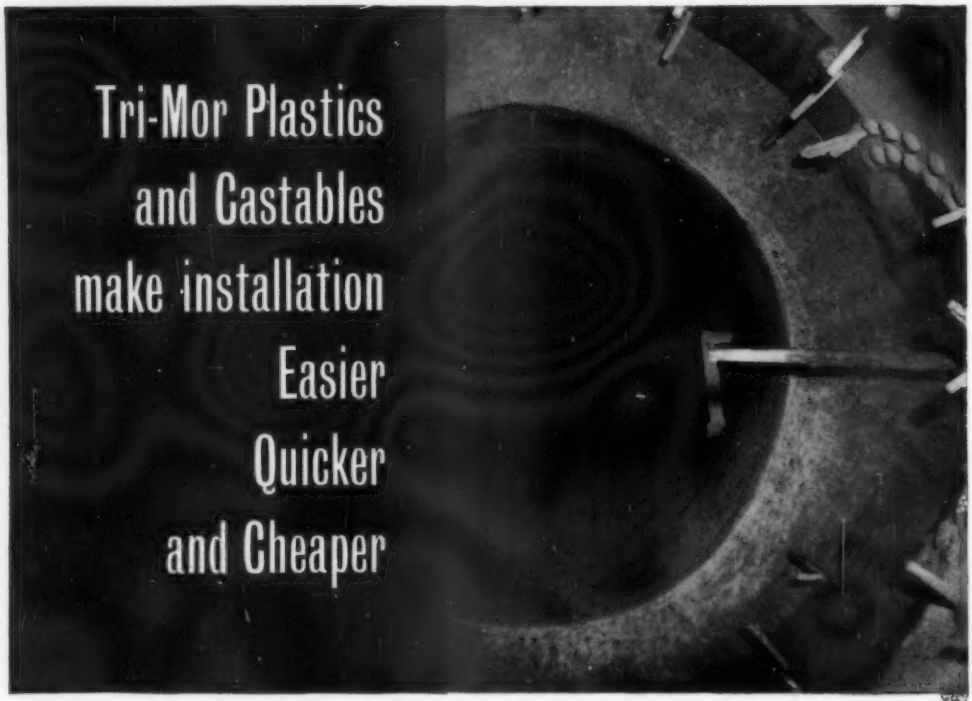

Bustle main of Queen Victoria Blast Furnace showing 'gunned' lining in Tri-Mor Dense 'Guncrete'.
(Inside diameter of shell 5 feet. Thickness of 'Guncrete' lining 9 inches).
Photograph by courtesy of the Appleby-Frodingham Steel Co. (Branch of the United Steel Companies Ltd.).

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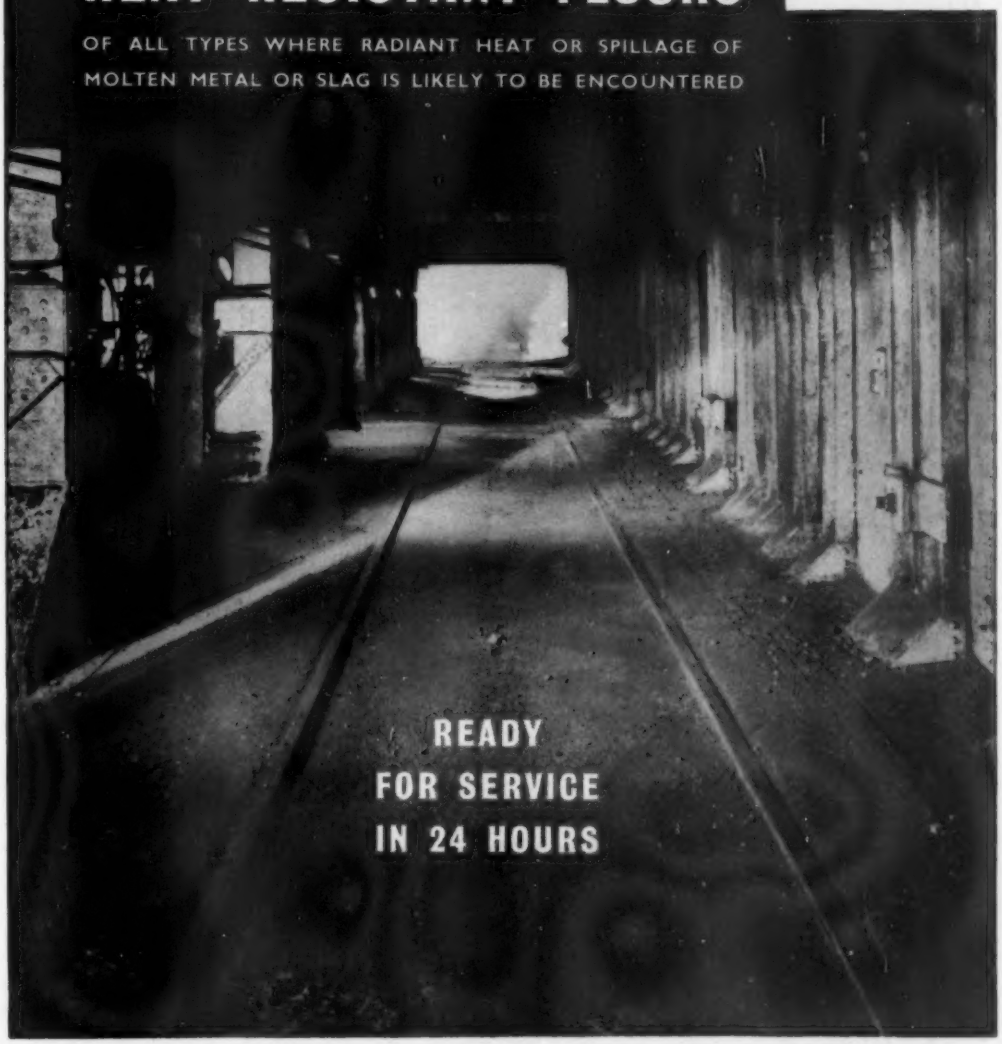

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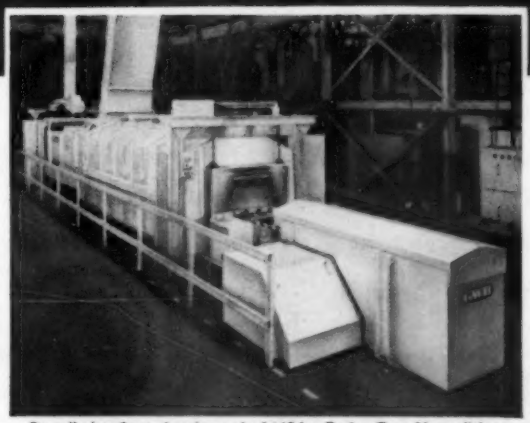

Overall view from charging end of 145 kw Pusher Type Normalising Furnace at Albion Motors Limited.

APPLICATION Various forgings such as main shafts, countershafts, pinion shafts and gear blanks are normalised by heating up to 900 C. and slow cooled down to 400/500 C.

AUTOMATIC OPERATION The only labour required is for placing the components into the charge trays at the entrance end of the furnace. By pressing a button, the following cycle automatically takes place. (1) The entrance door rises. (2) The pusher ram propels the loaded tray into the furnace. (3) The ram returns. (4) Entrance door lowers. (5) Exit door rises. (6) Hydraulically operated go-getter pulls last tray from exit end of furnace on to a cross conveyor. The cross conveyor moves the normalised parts to the top of an inclined roller track where the tray is unloaded by a tipper, and then returns empty to the entrance end of the furnace.

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June 1959

Vol 26, No 165

Metal treatment

and Drop Forging

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CONTENTS

This journal is devoted to metals—ferrous and non-ferrous—their manufacture, properties, heat treatment, manipulation, testing and protection, with research work and development in all these fields

223 **Vive La France!**

225 **Application of electron microscopy**
D. AND I. HRIVNAK

231 **Automation in forging**
SQN. LDR. S. C. WINFIELD-SMITH, D.S.O.

237 **Beryllium**

243 **Television in industry**
F. D. GRIMMER

246 **Non-ferrous metals research**

252 **New controlled atmosphere furnace**

We regret that owing to difficulties in the printing trade the number of pages in this month's issue have been reduced, and certain sections have had to be postponed.

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Vive La France!

OUR principal sentiments this month are those of gratitude and nostalgia; gratitude to the Syndicat National de l'Estampage et de la Forge for their extremely kind invitation which enabled us to attend the 3rd International Drop Forging Convention in Paris, and nostalgia for a wonderful week of hospitality and entertainment in that most beautiful of European capitals.

The entire convention was a model of its kind, everything had been thought of and everything was there, at the right place and at the right time. Technical sessions, works visits, sightseeing tours and entertainments all bore the stamp of careful planning and organization, together with that indefinable aura of civilized good taste which is essentially French—in fact is France's unique contribution to the Western way of life.

Most vivid in memory for all those who took part in this Convention will surely be the closing function which took place at the magnificent Chateau of Chantilly, about one hour's journey north of Paris itself. It may sound odd to report that dinner was served in the stables; that this was in fact the case simply underlines the magnificence of this ancient stronghold which, like many other pieces of property formerly belonging to the royal and noble families of France, has now passed into the public domain. A guard of honour was provided by men of the Moroccan regiment of Spahis, wearing their national costume of flowing, colourful garments and armed with swords; and at the conclusion of the dinner, when night had fallen, they exchanged these weapons for ' flambeaux,' to light the guests on their way. Not content with this, our French hosts also provided traditional music to go with a traditional repast, hunting horns which were sounded in the time-honoured fashion when the roast boar was served. The trumpeters were stationed in a circular gallery high up in the roof, and the sound of their music, the call and the answer, ringing and echoing around the ancient stone walls is one which will remain with us for a long time!

Time and other considerations do not permit of a full report of the Convention appearing in this issue, but we hope to be able to make good this omission shortly. Meanwhile suffice it to say that the city of Paris favoured us with excellent weather, the entire week was most enjoyable, and that even the staff of the ' Metro ' (a quick and cheap way of getting around when you know how) were considerate enough to postpone their 24-hour strike until the following week!

Dawning light?

In July, 1958, we made it pretty plain in these pages that we took a very poor view indeed of the fact that in the International Steelmaking Conference held at Liège the previous month not one of the papers dealing with the new oxygen-using processes came from a British author. This apparently stung our contemporary, *The British Steelmaker*, into a spirited defence of the steel industry. Pointing out, quite correctly, that the new oxygen techniques have been developed primarily as variations of the basic-Bessemer process, and that this process is in general more suited to conditions on the Continent than here, it concluded—' There is therefore just about as much sense in mewling over the absence of British papers in this field as there would be in deploring that seedless Jaffa oranges were not developed by the crofters of Rhum, Eigg and Muck.'

In saying this *The British Steelmaker* was partly right, but was not telling quite the whole story. Because equally one would not expect to find the crofters of Rhum, Eigg and Muck queueing up to board aircraft to visit Israel's sunny shores where the seedless

Jaffa oranges grow. But, on the other hand, we very much doubt whether there is now a single major British steelworks which has not at one time or another sent a man or a team of men to report on one or other aspect of these new continental oxygen processes. The somewhat smug attitude of '—— you Jack, I'm all right' is not justified by the present situation; nor does it enhance the reputation of a responsible periodical.

However, let us give credit where credit is due. The leading article in this month's *British Steelmaker*, which is headed 'Go and do thou likewise,' marks, we feel, a distinct advance. Discussing the extended use of oxygen the leader finally says . . . . 'But much more needs to be done. Incentive is not lacking now, and the British steel industry has the men and the means to match the recent achievements of the Continent'—which is rather a change from previous pontifications which seemed to imply that in the steel industry everything was technically for the best in the best of all technical worlds.

Where we would, however, part company is regarding the implied suggestion that all that is really needed is the application of oxygen to the open-hearth furnace rather than the adoption of oxygen-conversion techniques. Commenting on the paper presented by Dr. T. P. Colclough at the recent meeting of the Iron and Steel Institute the leader concludes that—'the moral for open-hearth steelmakers is clear, use oxygen to obtain the advantages of the new processes without losing the priceless qualities of adaptability and control.' Unfortunately this is a gross and dangerous over-simplification, the problems of the British steel industry cannot by any means be cured by the comparatively simple recipe of popping oxygen into existing open-hearths. If this were indeed so it is quite certain that a great deal more oxygen would be used than is the case at present.

The real problem is one of available raw materials and economic productivity for which there is no simple or straightforward 'nostrum,' but we salute *The British Steelmaker* for at last recognizing that a problem exists.

Supervisors and foremen

In October/November of last year, Mr. H. A. C. Tracey, general secretary of the Institute of Industrial Supervisors, visited the United States and studied the methods of American supervisors in industry. Mr. Tracey has reported his findings in his book 'Further Along the Road' which has just been issued by the Institute and the Birmingham Productivity Association.

In his conclusions, Mr. Tracey says that the features which impressed him most were not the differences but the similarities in the problems involved and in the activities undertaken to help the supervisor to resolve these problems. Certainly the American foreman has more encouragement to join a management club, but the practice of the best British companies does not lag behind the best American practice in this respect. More is being done in America by more people. The idea that foremen and supervisors need training and should play an active part in an organization of their own has had more years in which to become accepted and practised.

This does not mean that the American foreman is better than the British foreman—both are products of their industrial and national environments. It does mean that British industry should examine closely its plans for developing supervisors and should reconsider any help which it gives to local foremen's associations. Last, and by no means least, it does mean that British industry should consider what further help, direct or indirect, it might well give to the overall stimulation of improved standards of supervisory management in the United Kingdom through such agencies as the Institute of Industrial Supervisors.

Application of electron microscopy

Morphology of a brittle structural component in resistance-welded mild steel

D. and I. HRIVNÁK

In last month's issue, the authors described a study of the phase analysis of resistance-welded joints in carbon steels. The present article, translated from the original which appeared in 'Hutnické Listy,' 1958, XIII, No. 6, deals with the morphology of a brittle structural component which often arises as a result of resistance-welding mild steel. This is the fourth of a series of articles illustrating the role of the electron microscope in specific metallurgical investigations

RESISTANCE WELDING is characterized by the fact that the process of forming the metallic joint takes place in an extremely short space of time, normally less than a second. The study of the influence of the rapid heating and cooling on the structural changes in welded steels is extremely fascinating. At heating rates which exceed 1,000°C./sec., and cooling rates which are very frequently no less high, there occur various skeleton and incomplete transformations which it is quite impossible to bring about by any other intentional methods of heat treatment. Attention should also be drawn to the parallel influence of rapid induction heating, which is, however, more gradual by comparison.

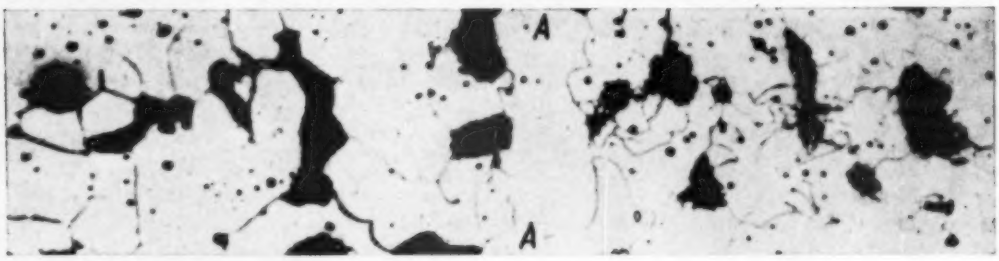
A phase analysis of resistance-welded joints in unalloyed and low-alloy carbon steels was presented in another work,[1] and a similar study of the morphology of incomplete $\alpha \rightarrow \gamma \rightarrow \alpha$ transformations was described earlier by one of the authors[2] of this present work concerned with the morphology of a brittle structural component which often arises as a result of resistance welding. In low-carbon ferrito-pearlitic steel the heat-affected zone which is subjected to temperatures in the A_1-A_3 range is characterized by the presence of retransformed pearlite.[1,2] Owing to the short period of austenitization, and also as a result of the high rate of cooling, the phenomenon may arise that the centre of the fusion zone, which prior to welding had been partly pearlitic, becomes hardened by the temperature sequences, while its border becomes pearlitic, and the surrounding base metal remains unchanged, *i.e.* ferritic. In the following work a study is presented of phase changes within the A_1-A_3 range of temperatures, on the basis of optical and electron microscopy research.

Experimental procedure

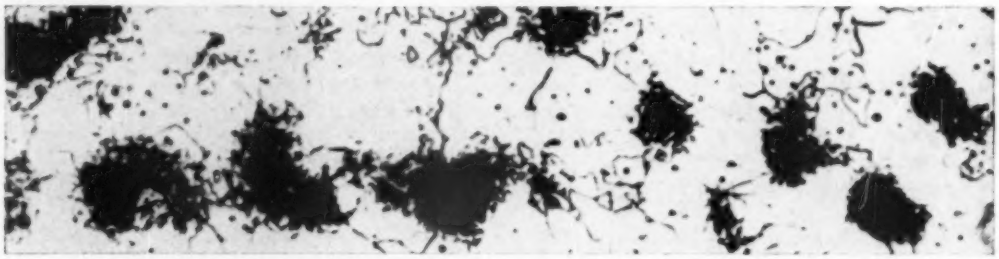
In this study of the morphology of the brittle structural component use was made of both of resistance-welded butt joints made on a welding press, and also of seam-welded scarfed joints. The material used for the experiments was unalloyed, mild steel with a content of 0·1 to 0·15%C.

The welding parameters will not be taken into consideration, since the work which is presented is in fact restricted to a study of the morphology of the structures occurring within the narrow heat-affected zone, where the prevailing rate of heating is greater than 1,000°C./sec., and the cooling rate is no lower by comparison.

All the specimens were prepared electrolytically for optical and electron microscopy in a solution of the type $HClO_4 + CH_3COOH + H_2O$ at normal current densities of 30 to 40 a./dm.^{2} and a voltage of 30 V. The specimens were polished in 2% HNO_3 in ethylalcohol for both methods of analysis. In order to identify the microstructure, the Hanneman system was used to measure the microhardness at a load of 50 g. on a Zeiss-Neophot microscope. Electron microscope investigation was carried out on negative collodion prints, shadowed *in vacuo* with a thin layer of chrome at an angle of 8 to 12 deg. And although the highest degree of resolution obtainable by this method did not amount to as much as 100 Å., it had to be used because the brittle component of the retransformed pearlite was in fact situated within an extremely



1 *Retransformed pearlite* 2% HNO_3 × 750



2 *Retransformed pearlite—later stage* 2% HNO_3 × 750

restricted heat-affected zone which could not be isolated.

Retransformed pearlite

As has already been pointed out, in the zone affected by the A_1-A_3 range of temperatures austenitization of the pearlite takes place in the ferrito-pearlitic complex structure, and diffusion of carbon occurs into the surrounding ferrite which has not yet been transformed. Under the influence of this diffusion austenitization of the bordering zones of ferrite commences. During the rapid cooling there is insufficient time for the retransformation process to be completed, and out of the former pearlite of the centre of the fusion zone there is dissemination of micro-colonies of pearlitic network structures (they may in fact be identified by means of electron microscopy), and the original orientations of the grain acquire a new form. An example of such a zone is given in figs. 1 and 2—the zone has been affected by a high temperature.

During resistance welding it is necessary to assume that the temperature gradient over the whole of the heat-affected zone is continuous. Therefore, the temperature affecting the zone shown in fig. 1 will rise gradually from the left-hand side to the right. Whereas, the retransformed pearlite and the surrounding ferritic grain in the left half of the micrograph have preserved their original orientation, from the centre of the micrograph towards the right-hand side the orientation changes abruptly. Around the retransformed pearlite there may be seen a network of fine ferritic grains; during a later stage in the period when they are affected by heating at a high temperature, there is transformation of these grains into retransformed pearlite (fig. 2). It is clear that the process of disintegration of the ferritic grains is very closely connected with the preferential diffusion of carbon in these directions, as has already been shown by electromicroscopy.[1]

As we put forward the hypothesis that at no point in fig. 1 has austenitization of the intimately included ferrite taken place, what then are we to regard as the reason why at the T_1 temperature, which applies to the left-hand side of the line A—A, where $\frac{T_2-T_1}{T_1} \approx 1$, this breakdown has been identified? Is the temperature T_2 ($A_3 < T_1 < T_2$) some sort of clearly defined temperature at which the carbon diffusion is fundamentally greater, or is this dependent on highly dynamic pulses of energy release, or is it the recrystallization temperature for this material? The recrystallization temperature is, however, lower than the A_1 temperature, and on the contrary recrystallization has taken place even on the left-hand side of the specimen. It is apparent that little is known about the mechanism

of the pearlitic transformation of sub-eutectoid steels to explain this and the many other phenomena which have been referred to.

In fig. 2 a further stage in the development of the retransformed pearlite is shown. And even though the pearlitic grains have not yet acquired their eutectoid composition, their structure is clearly pearlitic with extremely small interlamellar distances. This doubtless applies where the heating rate is high, but the cooling rate is relatively lower. But where the cooling rate is likewise high, the circumstance may also frequently occur that only the boundary zones of the pearlitic complex undergo the pearlitic retransformation; as a result the centre of the fusion zone will have the character of a disintegration phase consisting of ferrite saturated with carbon, with either a normal or a Widmanstätten orientation.

If the cooling rate is even higher, this central zone is neither pearlitic, nor does it consist of a disintegration phase, nor is it even martensitic. It may be made up of fine formations, sometimes with a lamellar orientation, in which disperse carbide particles predominate. Such a structure, which has formed not as a result of an isothermal transformation, but as the product of continual cooling, could not be compared with the disintegration product, heterogeneous martensite. The microhardness of this component reaches about 450 HV_m. The last stage of the retransformation of the former pearlite of the fusion zone at an even higher cooling rate is martensite, either with no surface relief (without texture) or with a slight degree of surface relief (with a fine texture). This is the brittle structural component in the overall phase analysis, the morphology of which was studied with very great care.

It must at once be recorded that this so-called brittle structural component is more frequently formed either through rapid precipitation or in zones which are affected by temperatures only slightly above the A_1 point, that is to say, in those areas where carbon diffusion into the surrounding ferrite has not yet become so intense that it has radically lowered the concentration of carbon in the central pearlitic zone. The morphology of this zone is illustrated by further micrographs (figs. 3 and 4). As may be seen, the central zone consisting of these brittle components has no texture, and in certain instances (fig. 4) further formations are precipitated with a higher carbon concentration and a somewhat higher hardness. As is evident from the indentations on the latter specimen, the microhardness of the brittle components was measured, and the hardness values were approximately 1,250 HV_m for the components without texture and 1,000 HV_m for the components with a fine texture. These hard central zones are bordered by a narrow zone of a disintegration phase, which is sufficiently sharply bounded, and in addition fine lamellae of cementite are clearly to be found in fig. 4.

On the basis of electron microscope analysis it may be judged that the boundary of the disperse cementite lamellae which surround the brittle component is the boundary of the carbon diffusion into the ferrite, and on the other hand the boundary between the disintegration phase and the brittle central zone is the boundary from which carbon was diffused. Study by means of electron microscopy explained the morphology of the two variants of the brittle component and of its transition into

3 LEFT *Retransformed pearlite with hardened nucleus* 2% HNO_3 × 500

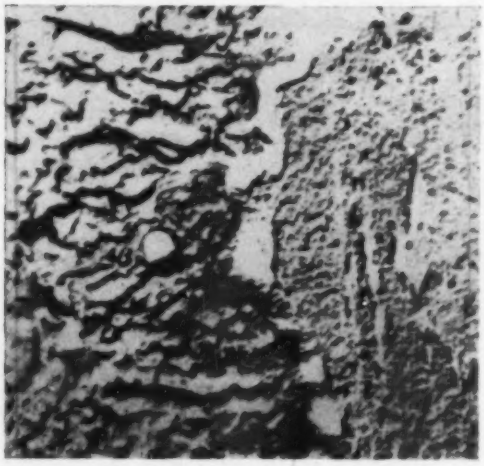
4 RIGHT *Brittle component* 2% HNO_3 × 500

the surrounding ferrite: that without texture and that with a fine texture.

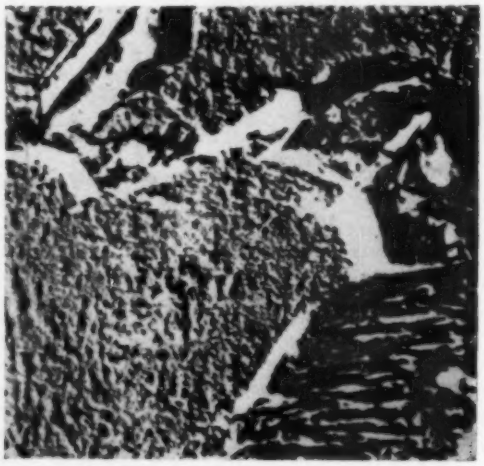
Morphology of the brittle structural component

First of all, an interpretation will be given of the brittle component with a fine texture. The transition zone between this structure and the ferritic border is shown in fig. 5. The left side of the micrograph shows the morphology of the boundary zones of the brittle component with finely precipitated carbides on the boundary with a lamellar tendency.

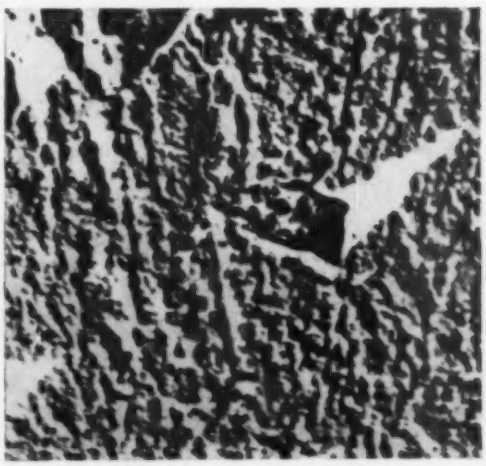
The transition from the brittle structure into the ferrite is extremely interesting. While the boundary between the brittle component and the disintegration phase is extremely abrupt, the lamellar cementite formations pass gradually and evenly into the



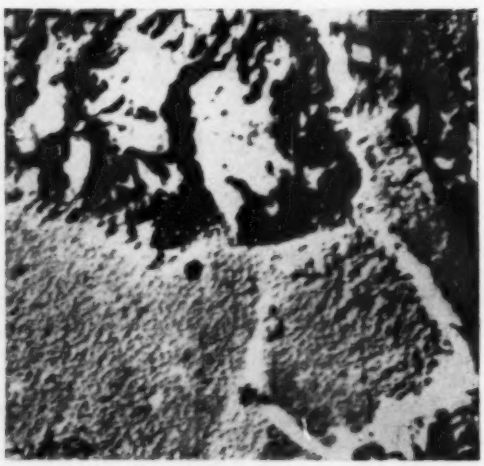
5 *Border of brittle component with fine texture*
2% HNO_3 × 12,000



6 *Structure with fine martensitic texture*
2% HNO_3 × 12,000



7 *Detail of internal structure*
2% HNO_3 × 20,000



8 *Brittle component without texture*
2% HNO_3 × 16,000

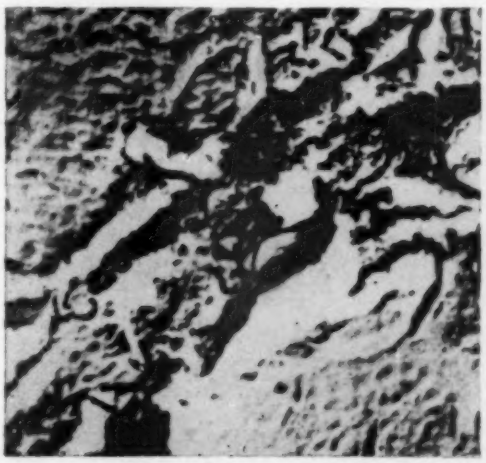
ferrite on the right-hand side of the micrograph. Thus, as the carbon concentration falls from the boundary with the brittle component in the direction of the super-saturated ferrite, so there is a corresponding growth in the interatomic distance of the pearlite. There can be no question but that the very fine pearlite in the vicinity of the abrupt change in concentration has a pseudo-eutectic composition.

In addition since the measurement of the interlamellar distance is of the order of 500 Å., according to Mehl[3] we may determine the corresponding temperature of formation as below 500°C. To what extent this assessment is accurate is impossible to guess, since Mehl, in determining the relationship between the interlamellar distance and temperature, made use of the isothermal breakdown of austenite, whereas in the instance under review it is a question of breakdown during continuous cooling; but at least one thing may be summarized, namely, that the transformation temperature of this pearlite was extremely low. And it is likewise certain that under otherwise constant conditions the interlamellar distance grows with the fall in the carbon concentration. Very disperse pearlite changes gradually and evenly into ferrite on the right-hand side of the specimen.

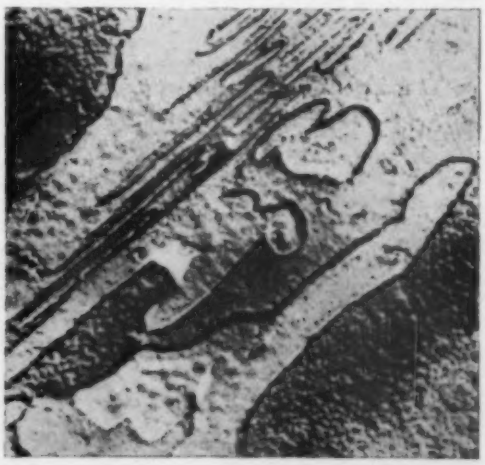
How may the fact be explained that the transition from the very fine pearlite into the brittle component (martensite with a fine texture) is abrupt, without a gradual and even fall in concentration? It is true that not only here, but in other instances also, we frequently come across the fact that, either under otherwise similar conditions of the thermal factor, and during an even and gradual drop in concentration, or where the concentration remains constant and there is an even and continuous change in the thermal factor, sharp structural boundaries occur between the transformation products.

Apart from this, fig. 1, in which this problem is clearly formulated, brings to mind the following instances. From previous information concerning the course of the transformation into pearlite+martensite it follows that pearlite is formed at appreciably higher temperatures than martensite, and its formation is clearly indicated by nucleation and growth. Therefore, if it were a matter of heterogeneous austenite, the nucleation rate would be great, and at an intense cooling rate the main growth would cease at a certain concentration and temperature at which the diffusionless transformation became the preferential reaction. This would be evidence of the fact that these transformations are precisely limited by energy functions and probably quantized.

Fig. 6 illustrates just such an instance. It is an example of a brittle component with a fine texture, in which at some points are precipitated lamellar carbide formations. The transition into the surrounding ferritic zone is similar: first of all without a gradual and even change we have fine pearlite, which in this instance passes over into disintegration phases and ferrite supersaturated with carbon. On the other hand, the detail of the internal orientation of the brittle structural component with a fine martensitic texture under very high magnifications is illustrated in fig. 7. In the



9 *Brittle component with crystalline substructure*
2% HNO_3 × 15,000



10 *Non-lamellar cementite with substructure*
2% HNO_3 × 7,000

the surrounding ferrite: that without texture and that with a fine texture.

Morphology of the brittle structural component

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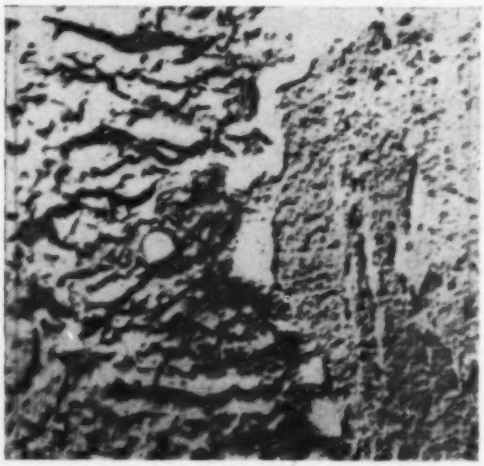
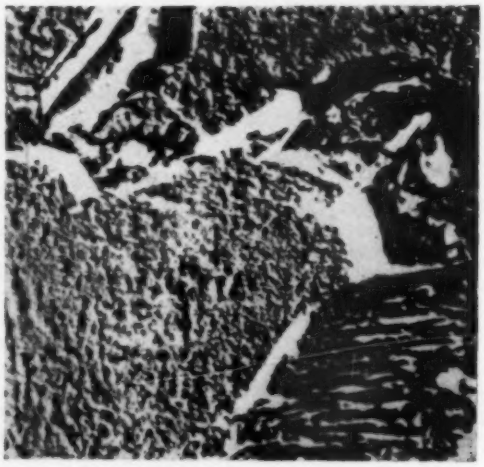
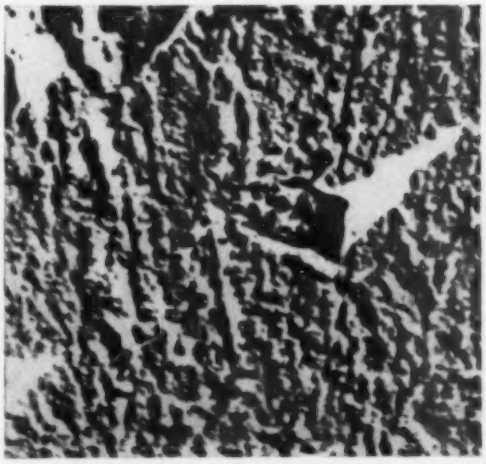


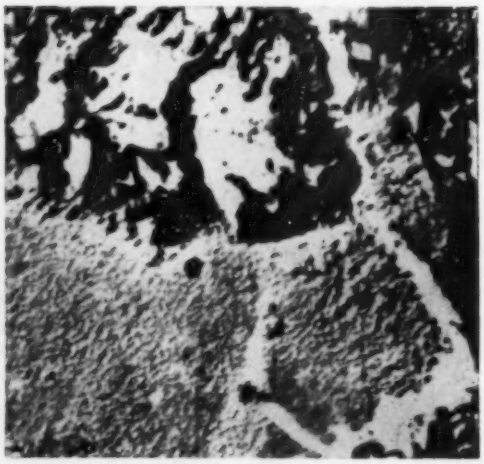
5 *Border of brittle component with fine texture*
2% HNO_3 × 12,000



6 *Structure with fine martensitic texture*
2% HNO_3 × 12,000



7 *Detail of internal structure*
2% HNO_3 × 20,900



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2% HNO_3 × 16,000

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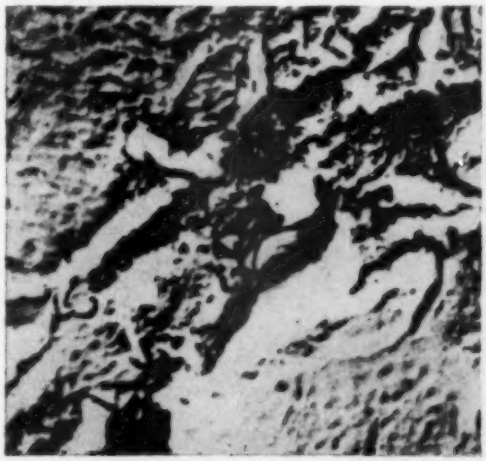
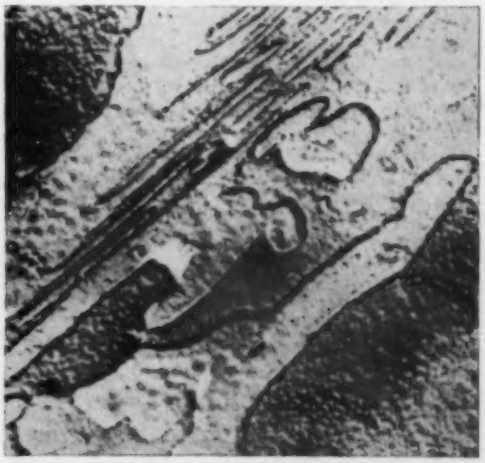
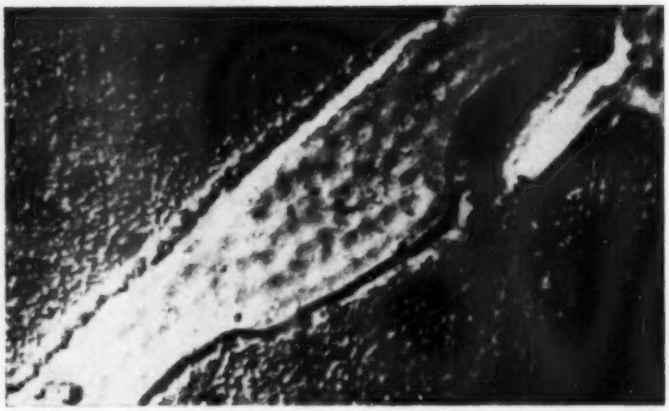


9 *Brittle component with crystalline substructure*
2% HNO_3 × 15,000



10 *Non-lamellar cementite with substructure*
2% HNO_3 × 7,000



11 *Non-lamellar cementite with substructure* × 13,000

basic matrix are visible finely dispersed carbides which at some points form peltate complex structures. Apart from these, there are also to be seen larger peltate carbides which stand out prominently against the basic matrix.

The brittle components without texture have a dual orientation. Fig. 8 typifies these components with a high microhardness of about 1,300 HV_m. As may in fact be seen at these high magnifications, the surface is shown to be smooth without any special morphological characteristics. Once again there is an abrupt transition into a very fine pearlitic phase, which passes more or less gradually into the ferritic surround. The other example of the brittle component without texture is remarkable. Such a transition is shown in fig. 9. Whereas the right-hand side of the micrograph is typified by ferrite with a close-packed structure, the transition into the zone of the brittle component is marked by similar disintegration phases to those in the preceding instances. In this instance, however, the brittle component without texture has its own morphology! If we make a more careful examination of the bottom left-hand part of fig. 9, a lattice substructure may be seen even at a distinct distance from the boundary. What does this substructure mean?

Let us examine fig. 10. This does not even show the zone of retransformed pearlite, but the zone affected by temperatures around, but below, the A_1 point. The pearlite in this hyper-eutectoid low-carbon steel was precipitated in fully developed lamellar formations. As a result of the effect of temperature cementite lamellae started to form, but on cooling did not crystallize as lamellae. The ferritic panel alone has preserved its lamellar form intact (fig. 11). On the other hand, this non-lamellar cementite once again has a crystalline substructure. This substructure is even more clearly to be seen from fig. 11.

In connection with this phenomenon it should be pointed out that the authors observed a similar substructure in the α-phase in 16 Cr-13 Ni austenitic steel.[1] which, as Malik[4] has shown by X-ray analysis, conforms to orthorhombic lattice parameters. The same distinct substructure has also been revealed by the authors in carbides of 1·19% C, 1·24% Cr steel, probably of the type $(Fe, Cr)_2C$, which can likewise crystallize in the orthorhombic system. On the other hand, cementite, Fe_3C, also possesses orthorhombic lattice parameters.

The conclusion to be drawn from this would seem to be the very plausible possibility that the crystalline substructure which has been mentioned, and which in many instances has fully developed hexagonal formations, be they perfect or imperfect, is characteristic of crystallization in the orthorhombic system. How then should one explain the fact that after several months' storage at normal temperature, in common with other physical properties, the morphology of the α-phase also changed so that the crystalline substructure became imperceptible? On the other hand, in hyper-eutectoid steel the crystalline substructure has been identified after a different heat treatment. Since cementite crystallizes in the orthorhombic system, why then is the crystalline substructure to be found in the non-lamellar cementite which had its origin as a result of a rapid transformation, *i.e.* by heating and cooling? Does this substructure perhaps reveal some sort of transition state in the growth (formation) of these components, *i.e.* some sort of metastability of the concentration, or some combination of the solidifying elements, which

continued on page 236

Automation in forging

SQN. LDR. S. C. WINFIELD-SMITH, D.S.O.

The following article is based on a lecture given by the author at Dudley Technical College, December 11, 1958. *Sqn. Ldr. Winfield-Smith discusses the development of some of the Eumuco automatic forging equipment*

COMPARED WITH STRETCHING (FULLERING) under an air hammer, the use of stretching rolls shows a considerable increase in output, and work on a stretching roll can be adjusted to the die forging operation. But the output of the stretching roll as known in this country is limited by manual loading. Automatic loading for a standard stretching roll would be very complicated, as the component must be reciprocated in the rolling direction and furthermore moved horizontally from impression to impression, being rotated at the same time. The clamping and unclamping of the component must be added, as well as the bringing back of the feed mechanism to the initial position. All these considerations compelled Eumuco to look for a completely different design of stretching roll in their solution for the automation of this type of machine.

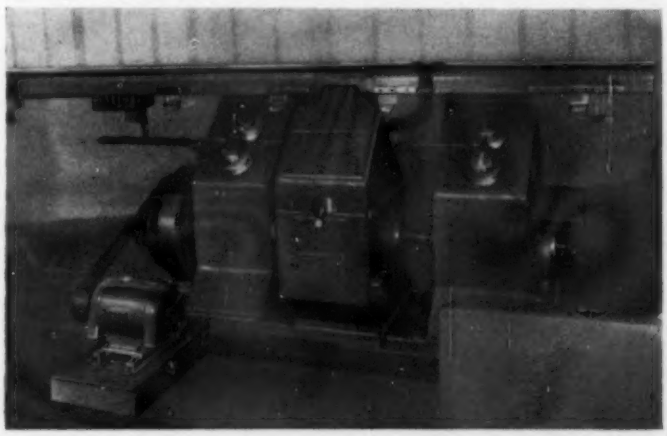
Multi-roller stretching machine

In the case of the new design the rolling segments are not arranged side by side, but in pairs behind one another offset at 90 deg. The number of the pairs of rollers must correspond to that of the passes required. A guide trough as shown in Fig. 2 is situated between the pairs of the rollers and is adapted to the appropriate diameter of the initial material. In the case of the automatic stretching roll shown here there is only one direction of transport, namely the rolling direction. Transport is effected with a feed carriage which has a swivelling feed finger to push through the rolls. The carriage is driven by a small electric motor through a friction drive, so that differences in the feed speed of the carriage and the rolling speed are automatically compensated.

Every pair of rollers is arranged as a self-contained unit and has its own drive through a common shaft on to which the clutch and the brake are fitted. These units are mounted on a frame and can be moved along the frame to comply with the length of the component to be rolled.

The components are automatically fed from the heating plant to the roll. The most suitable heating appliance in this instance is an inductive heating plant. After the component has been loaded the movement of the feed carriage is started at the moment when the component comes up against the stop of the first pair of rollers.

As the clutch is mounted on the common shaft all rolls make a revolution simultaneously. During



1 *New design Eumuco multi-roller stretching machine*

the rolling operation the carriage follows the component driven by the friction drive. After the first pass has been completed, the feed carriage moves the component forward until it runs against the stop of the second pair of rolls and the roll is started again. The above process is repeated at every pair of rolls until the component is finished.

The rollers are started by adjustable contacts on the slideways of the feed carriage; the slideway of the feed carriage can be arranged in such a way that the component can be transported to the tools of the following machine, either a press or hammer, for further operations, after which the feed carriage returns to its initial position, where it picks up a new billet from the heater. It is quite possible to feed the roll with a constant supply of billets so that practically a component is in every pair of rolls and that a finished component leaves the machine at every revolution. This, however, is only possible if the subsequent hammer or press can handle this amount of components.

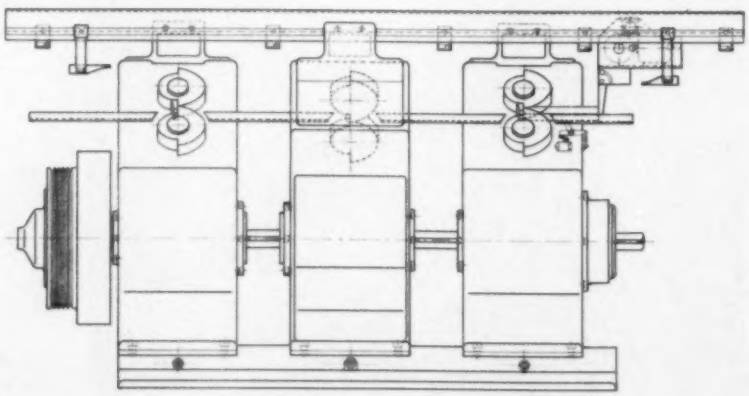
2 *A guide trough is situated between the pairs of rollers*

The supply of two or more hammers or presses can be made possible, however, by using a chute in the form of a Y with a trip on the Y so that the rolled billet can be switched from one leg of the Y to the other automatically.

The side view of the machine shows the drive of the two roller shafts through a pair of gears. The transmission through the common drive shaft is effected through a pair of bevel gears. The upper roll is carried on an eccentric bush and can be adjusted by rotating this bush. In the same way with the gear wheel on the upper gear the play can be adjusted.

If the components are long enough to be gripped by the next pair of rollers when leaving the previous one, the special feed arrangement is not necessary and the roll can run constantly, which would increase the output still more. A roll on which billet diameters of approximately 1·8 sq. in. can be pre-rolled, for example, is shown in Fig. 3. In the case of three passes this would have an output of 12—20 pieces per minute, giving a cycle time of 3—5 sec.

When rolling motor-car connecting rods, bicycle cranks, etc., an automatic cropping machine is in use which crops off the bars to the right length; the billets then automatically pass to a V-shaped



3 *Schematic diagram of method of operation of the rolls*

hopper. By means of a big magnetic wheel, where the magnets are in sections, the billets are picked up and when they get to the top they fall out and are fed into an induction heater. When this is full it automatically stops the wheel, which waits until the billets have been passed through the heater to the automatic roll-forging machine. They then pass to the press or hammer where they go through the next operation, then to the clipping press where they are trimmed and straightened.

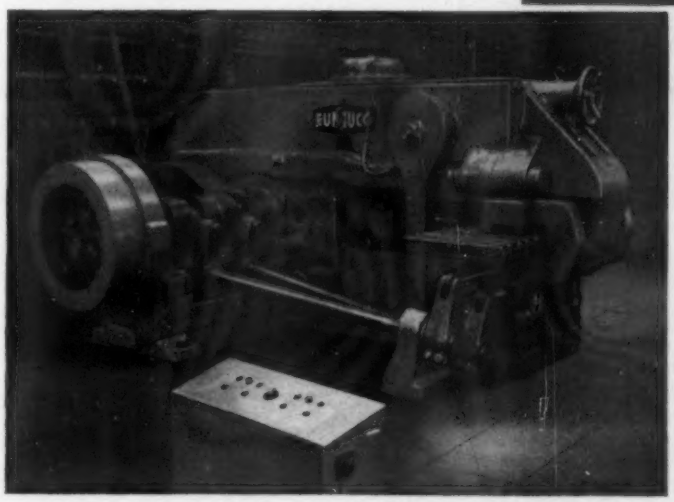
The labour used on these machines is one labourer feeding bars to the cropping machine, one skilled man on the press, and a semi-skilled man on the clipping press giving an output of connecting rods or bicycle cranks of two every 10 sec.

Horizontal forging machines with automatic feeds

Fig. 4 shows a horizontal forging machine with automatic workpiece feed by means of revolving plate. The machine has been developed for finish-pressing and trimming valves for car engines. Four pressing dies have been accommodated in a vertical revolving plate. Pressing punch and trimming punch are mounted on the pressing slide. The revolving plate is moved by a Geneva motion, the drive of which is derived from the transmission shaft of the machine.

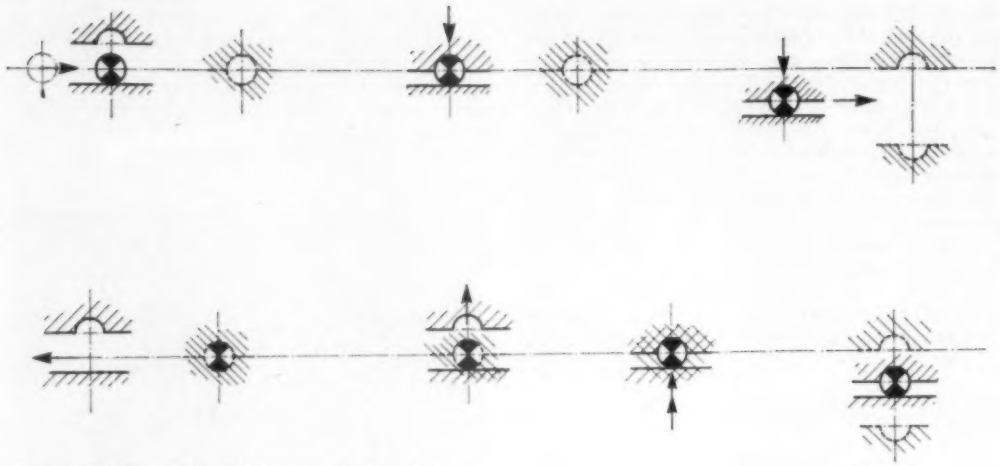
The valve stock with the heated end is brought to the first pressing die with the aid of a loading device. During the work stroke the pressing ram pushes the stock into the pressing die. After each work stroke during the return motion of the pressing slide the revolving plate is rotated through one division. During the next stroke the valve is pressed, during the third stroke de-burred and ejected. After trimming, the valve drops into a container. Using this method approximately 40 valves can be pressed in a minute which corresponds to a cycle time of 1·5 sec.

The vertical position of the revolving plate was



4 ABOVE *Horizontal forging machine with automatic revolving plate workpiece feed*

5 LEFT *Forging machine with horizontal clamping jaws and feed attachment*



6 *Run of bars through the forging machine shown in Fig.* 5

selected because it makes possible a simple and reliable feed for the pressing tools or punches. The machine works in continuous operation, but can be switched over to individual strokes at any time with the aid of an electro-pneumatically controlled friction clutch. The machine is automatically stopped as soon as no new stock is fed to it.

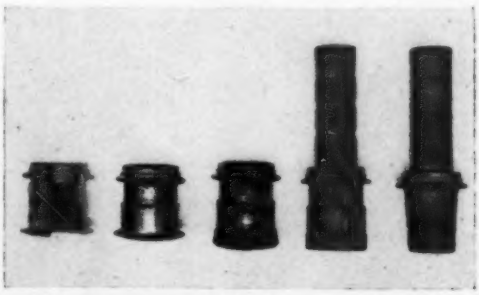
The machine has been designed to give a tolerance of ·01 mm. on the valve head. Therefore, as in the case of similar machines, with automatic operations a great deal of importance has been attached to efficient cooling, cleaning and lubrication of the impressions and as simple as possible mounting and dismantling of tools.

In the case of a forging machine with horizontal clamping jaws, when it was redesigned some years ago, the clamping jaws were closed through a toggle lever system. The two lateral grippers form a part of it. In the case of this design the clamping jaws of the machine are completely free and the upsetting punches are freely accessible from both sides of the machine. These features of the design are admirably suited for automation of the horizontal forging machine. Dies and punches can be changed in 10 min.

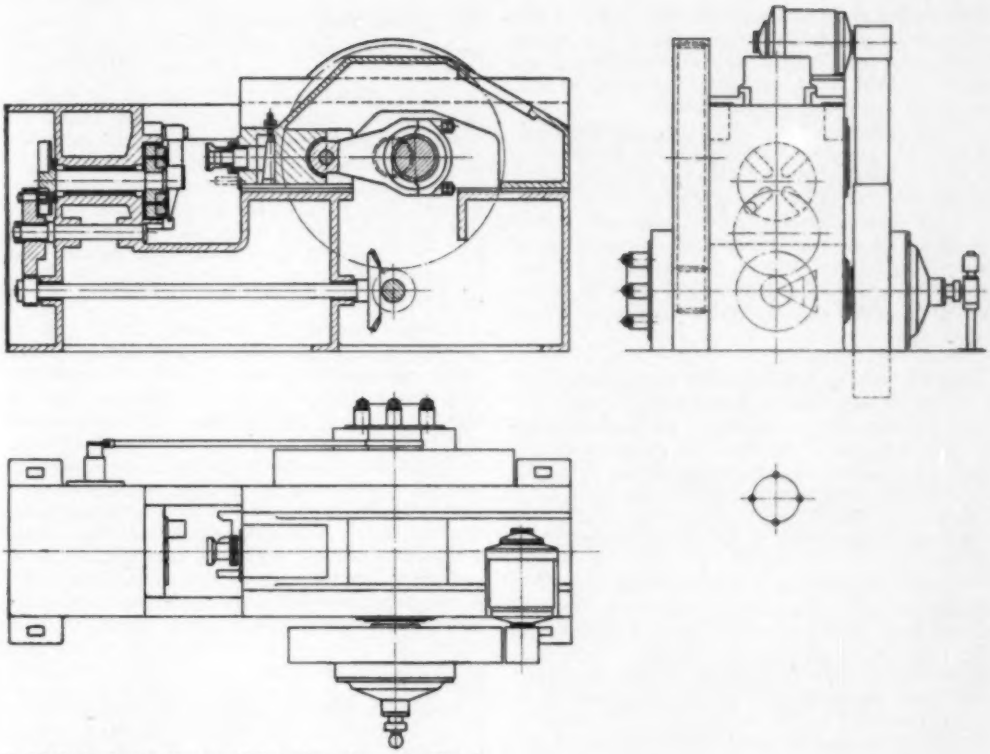
Fig. 5 shows a forging machine with horizontal clamping jaws to which a feed attachment has been built. It is mainly used for upsetting bars of a limited length, for example, motor car half shafts, torsion bars, valve push-rods, set bolts, etc.

A bracket-type slide moves horizontally and vertically in front of the clamping jaws and carries a clamping bar which has semi-circular recesses. These recesses correspond to the bar diameter and their division to the division of the tools. The clamping plate is lifted with the aid of a wedge bar and the bars are clamped between the notched clamping bar and an upper smooth clamping plate. The slide is moved from one impression to another with the aid of a lever shaft driven by a cam disc mounted on the camshaft. The wedge bar is driven in the same way; the only difference is that its stroke round the clamping travel is larger. The clamping of the bars and the movement from impression to impression is positive. They are lifted from the impression by means of an air cushion which lifts the whole clamping stirrup upwards when the clamping impression opens. Then the top part of the clamping jaw descends, the clamping stirrup is pressed down and the bars are inserted in the impression.

The run of the bars through the machine is seen best if the movement of an individual bar is followed (see Fig. 6). The bar is placed automatically from the heating plant to the locating position in



7 *Bicycle hubs made on forging machine shown in Fig.* 5



8 *Method of operating revolving plate shown in Fig.* 4

front of the clamping jaws of the machine. Then the lower clamping bar moves upwards and locks it. While this is done the clamping jaws are still closed. As soon as they open, the clamping stirrup with the bar moves upwards and subsequently to the left. This brings the bar above the next impression. When the clamping jaws close, the clamping stirrup with the bar is pressed downwards and the bar is inserted in the impression in the lower clamping jaw. After the clamping jaws have been closed, the usual upsetting operation is effected during which the clamping arrangement opens, the clamping stirrup moves freely backward, all bars remain in their positions, and the above process is repeated. Should long bars be machined, the feeding device works in the same way, only the clamping stirrup is then open to the operating side of the machine and closed to the upsetting side.

With the aid of such mechanical feeding device every stroke of the machine can be used so that a finished component is ejected each time. In many cases the machine will be fed every second stroke so that the individual impressions alternatively would not be used during one stroke which facilitates the blowing-out, cooling and lubricating of the tools. The automatic performance of these three auxiliary operations is a condition for satisfactory automatic working of the machine. In spite of the mechanization, the tools and the feed mechanism itself are easily accessible so that checking, setting and changing of the tools can be effected very quickly.

In order to obtain a completely automatic operation of these machines, an automatic conveyor delivering the bars from the heating plant to the machine, adapted to the local conditions and particular requirements, must be provided.

As compared with the usual forging machines, in the case of automation, the number of strokes is reduced by approximately 20% as otherwise the times for the movement of the feed mechanism would be too short and the forces of the mass too large. In the case of a small automatic machine an output up to 40 pieces per minute can be obtained and in the case of larger machines, of, say, 450 tons, the output of 30 pieces per minute could be obtained.

This would mean a work cycle of 1·5 and 2 sec. respectively. This shows quite clearly that in this instance, if even the machine works a little slower (and therefore more reliable), the work is done much quicker than by hand feeding.

When using automatic machines, a larger model should be selected than would be required on a manual loading machine, as the specific load is considerably higher. The energy of the fly-wheel and the drive motor must be adapted to their respective uses and it must be borne in mind that, while the energy of the fly-wheel in most cases will suffice, the drive motor must be larger, as the fly-wheel will have to be ' recharged ' more often.

Transfer line of machines for valve push-rods

A transfer line for the production of valve push-rods consists of four machines working in pairs. On the first pair of machines the induction-heated rods are upset hot and subsequently are subjected to sand-blast treatment, annealed and brought to the second pair of machines on which they are calibrated cold. The tolerance should not exceed 0·00039 in.

In this connection it should be pointed out that chains are used, not only for transporting the rods to and from the machines, but also for transporting the components through the machines themselves, as the components are relatively small. For larger and more heavy articles the gripper conveyor is more suitable.

The advantages of mass production of forged articles provided by automation of forging machines are considerable, and have been proved on the Continent where car manufacturers have been disappointed with their supplies, not only from the point of view of deliveries but also by the rough finish of articles and high price. The British forging industry should consider getting together and reducing prices or history will repeat itself.

NADFS prize competition

The National Association of Drop Forgers and Stampers announces three awards of up to £50 as a prize for written papers on a subject directly related to ' The production and processing of forgings.' For details apply to the Technical Officer, 245 Grove Lane, Handsworth, Birmingham, 20. Closing date September 1, 1959.

President Academician, J. Cabelka, for facilities to carry out the necessary experiments.

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Electron microscopy

concluded from page 230

would be transitional in the case of the α-phase and cementite, whereas in the complex carbides it would be more permanent through the influence of the Cr content? Any other explanation would be difficult to find, but even this does not throw entirely clear light on the problem, and in order that the phenomenon of the internal substructure may be explained, many more experiments must be conducted not only morphologically but also by X-ray micro-analysis.

In every instance the conclusion drawn leads to the opinion that the brittle component with the lattice substructure seen in fig. 9 is identical with the non-lamellar cementite to be seen in figs. 10 and 11. But how does this non-lamellar cementite with a high carbon content of 6·67% arise, while alongside this phase over the same restricted area pearlitic grains with a eutectoid concentration of 0·86% C are distributed? It must be emphasized that neither the morphological nor the transformation problems, which are associated with the very high heating and cooling rates, have been thoroughly investigated, and therefore in this connection every phenomenon is a new one.

Conclusions

Data were obtained by means of electron microscopy concerning the morphology of a brittle structural component arising during resistance welding of low-carbon (0·1 to 0·15% C) low-alloy steel, and this phase is described. Basically there exist two morphological groups of brittle components: those without texture and those with a fine martensitic texture. Whereas the morphology of the brittle component with a fine texture is shown in figs. 5, 6 and 7, that of the brittle structure without texture is shown in figs. 8 and 9. The authors draw attention to the modification of this component with a crystalline substructure as seen in fig. 9, and even more distinctly in figs. 10 and 11, even though the last two micrographs are taken of a structure which was affected by a lower temperature. While no definite conclusions may be drawn concerning the cause of the formation of this substructure, it is none the less possible that this structural component shows signs which indicate metastable crystallization in the orthorhombic system. The solution of this problem calls for further study.

Acknowledgments

The authors wish to thank the management of the Welding Research Institute, and especially its

Beryllium

A panel to study the problems and possibilities of beryllium as a structural material was recently organized by the Materials Advisory Board of the National Academy of Sciences—National Research Council, sponsored by the U.S. Department of Defence. The following report is based on the summary given by Mr. J. R. Lane, staff metallurgist of the Board, in 'Journal of Metals,' November, 1958

UNTIL ABOUT TEN YEARS AGO, beryllium metal was generally considered to have practical utility only as a nuclear material. Even in the nuclear engineering field, its uses were severely limited by the fact that the only forms in which the metal was available were lumps, granules, and small castings of poor physical properties, and by the fact that the machining of the castings was difficult and costly.

By 1950, powder metallurgy techniques had displaced casting almost completely for producing the billets and blocks that are the starting materials from which finished metal shapes are fabricated. The fine grain size of the powder metallurgy billets increased the ductility and malleability of the metal sufficiently to permit machining of beryllium into parts of very intricate design to the highest standards of precision.

Pure beryllium in the forms available today does not have the ductility of the common light metals, nor does it appear likely that this desirable characteristic will be achieved in the near future. Offsetting the lack of ductility, however, are beryllium's outstanding physical properties of low density, high strength to density ratio at room and elevated temperatures, high specific heat, and its very high modulus of elasticity. Beryllium's possession of these properties and its limited availability now in a number of sizes and shapes entitle pure beryllium metal to consideration among the other modern engineering materials.

Beryllium, at present and in the foreseeable future, is relatively costly to buy and expensive to fabricate. In spite of the advantages that may be claimed for general use of beryllium in airframe structures, the high cost of raw material and fabrication procedures will place a practical limit on its use.

The opinion of the panel was that the development of major new sources of beryllium was within the bounds of possibility, and that price incentives would contribute to this. However, major developments were likely only over a long period, and only if sustained efforts were made along the lines of research in extraction and in the factors that govern the occurrence of beryllium in the earth's crust.

Ductility

Metallic beryllium has been prepared and studied by many people throughout the world. All of them have found beryllium to be relatively brittle, and this shortcoming has been the chief deterrent to the use of beryllium for structural purposes.

Composition Beryllium of commercial purity contains about 0·1% Al, 0·1% Fe, 0·05% Si, 0·2 to 1·0% O_2, and approximately 0·005 to 0·01% of other common metals, such as Cu, Ni, and Cr. A number of studies in the past have indicated that beryllium which is substantially purer than the above does not have noticeably different properties.

Forms of beryllium Commercial beryllium can exhibit widely different values for ductility in tension at room temperature, depending upon its method of fabrication, grain size, and preferred orientation. These differences occur with no significant change in impurity content other than variation in the amount of oxygen. This variation in oxygen above the solubility limit (which is exceedingly low) appears to have no effect on the results.

Vacuum-cast beryllium has the lowest oxygen content of any commercial form and is the most brittle, having essentially zero ductility at room temperature. An extrusion made from such a casting will exhibit 2 to 3% elongation in tension and 20% contraction in compression. This improvement may be attributed to refinement of grain size and development of a texture. Vacuum-cast beryllium may be converted to powder and reformed by various powder metallurgical techniques. Such material exhibits 1 to 2% elongation. As a result of making powder, the oxygen content is increased from about 0·2 wt.% to about 1·0 wt.%.

Powdered beryllium, if extruded at about 1,040°C., exhibits 15 to 20% elongation in the extrusion direction. The preferred orientation appears to be identical with that which is achieved in extruded cast beryllium.

Powdered beryllium may be formed into sheet by various procedures which produce a highly developed texture, wherein the basal planes are all close to the plane of the sheet. Such material, if processed under optimum conditions, can exhibit 30 to 40% elongation under conditions of uniaxial strain in any direction in the plane of the sheet. In the thickness direction the ductility is very low, and as a result, a biaxial tension strain readily leads to fracture.

Effect of impurities on brittleness

A great many people have studied beryllium and tried to make pure forms of it in order to achieve ductility. The net result of this work was the general conclusion that removal of impurities would not make beryllium a ductile metal.

Non-metallic impurities It is conceivable that oxygen could lead to brittleness in beryllium as it does in titanium and zirconium and a number of other metals. It has not been possible to date to determine whether oxygen is measurably soluble in solid beryllium or to identify an oxide phase. Numerous attempts have been made and are still being made to produce oxygen-free beryllium by special procedures, such as distillation in high vacuum, electrolysis from organic compounds of beryllium, thermal decomposition of beryllium iodide, and vapour phase reduction of beryllium chloride with sodium.

It is also conceivable that nitrogen and carbon might embrittle beryllium. As far as is known, this question has not been extensively explored. The most that can be said is that some samples of beryllium containing less than 0·05 wt.% N and C did not exhibit unusual ductility.

Metallic impurities Work in the last ten years has not drastically changed the opinion of early investigators that removal of metallic impurities will not lead to increased ductility.

Recent work shows definitely that iron additions up to 0·5 wt.% progressively reduce the elongation of ductile sheet. Nickel additions up to the same amount cause less of a reduction, while copper appears to have no effect on ductility. Extrapolation of the ductility curve for iron does not indicate that iron-free beryllium would have remarkably increased ductility. This work was concerned with fracture on the 1120 planes. It is not known what effect, if any, these impurities have on the basal planes.

Possibility of health hazard

No applications of beryllium should be planned without a full appreciation of the toxicity of this metal and its compounds. A Materials Advisory Board Panel on the Toxicity of Beryllium has recently prepared a report on this subject, from which the following remarks are abstracted.

In contrast to former beliefs, no reasonable doubt now remains that small amounts inhaled have produced an acute disease (pneumonitis) and/or a chronic disease (granulomatosis), the latter having a high mortality rate. Contact with certain beryllium compounds can produce a dermatitis which may be serious with respect to lost time, but which can be combatted with suitable protective clothing or skin creams.

Protection against beryllium poisoning is largely a matter of controlling the dust evolved in the operations on the metal. As a target figure for the

TABLE I *Tensile and compression properties of beryllium produced from powder*

	Ult. tensile strength (lb./sq. in.)	Yield strength 0·2% offset (lb./sq. in.)	Modulus of elasticity (lb./sq. in.)	Poisson's ratio	% Elongation in 2 in.	% Reduction in area	Compression yield strength, 0·2% offset (lb./sq. in.)	Compression modulus of elasticity (lb./sq. in.)
Vacuum hot pressed Q.M.V. Beryllium block	35,000-45,000	25,000-40,000	$42\text{-}44 \times 10^6$	0·024	0·5-3·0	0·5-3·5	25,000-35,000	$42\text{-}44 \times 10^6$
Hot extruded beryllium								
Longitudinal properties								
Extruded at 1,000-1,100°C.								
12 : 1 reduction ratio								
Annealed at 750°C.	60,000-100,000	40,000-55,000	$41\text{-}44 \times 10^6$	0·032	8-16	—	35,000-40,000	$42\text{-}44 \times 10^6$
Warm extruded beryllium								
Longitudinal properties								
Extruded at 430°C.								
5 : 1 reduction ratio								
As extruded	85,000-100,000	80,000-90,000	$42\text{-}44 \times 10^6$	0·030	0-1	—	85,000	44×10^6
Annealed at 760°C.	60,000-90,000	45,000-55,000	$42\text{-}44 \times 10^6$	0·030	2-5	—	50,000	43×10^6
Hot rolled beryllium								
Sheet (900°C.)								
30 : 1 reduction in area with some cross rolling								
Longitudinal	50,000-56,000	35,000-50,000	$41\text{-}44 \times 10^6$	—	1-4	—	—	—
Transverse	40,000-55,000	35,000-50,000	$40\text{-}44 \times 10^6$	—	0·5-2	—	—	—
Warm rolled beryllium								
Sheet (650-790°C.)								
Longitudinal	80,000-90,000	60,000-70,000	44×10^6	—	5-10	—	—	—
Transverse	80,000-90,000	60,000-70,000	44×10^6	—	5-10	—	—	—

average allowable concentration of beryllium in the air, 2 μg./m.³ may tentatively be acceptable. This does not constitute a guarantee that no chronic illness will develop; there are cases in which a lag time as long as 16 years intervened between exposure and symptoms.

To keep airborne beryllium at the required low level, the following principles are suggested:

1. Manual handling should be reduced to an absolute minimum.
2. Every implement which has been in contact with beryllium should be regarded as contaminated, and therefore a potential dust source.
3. Every process step should be examined critically to determine whether by arrangement or substitution it can be made less dusty.
4. Essentially every process step must be provided with some degree of ventilation. The only effective method of control is to contain and remove the dust at its source.

Structural considerations

Since beryllium has been used chiefly in nuclear applications, there has not been a need for many of the mechanical data usually used by aircraft designers. Characteristic strength values are given in Tables I and II.

Ductility The attainment of a reasonable amount of ductility in all directions (in turn, not necessarily simultaneously), including the thickness direction, is required if beryllium is to be a reliable structural material for extended use in missiles and aircraft. Without this amount of ductility only limited applications are likely. Many of these applications would require the generally weaker but more ductile grades, and as a result the gain in performance compared to competitive materials may not be great.

Suitably worked or annealed beryllium may exhibit substantial ductility in a tensile test. However, this material can fail in a brittle manner if a wide piece of sheet is bent, or stresses occur simultaneously in two directions. The optimum preferred orientation responsible for the highest tensile ductility in the pane of the sheet permits no significant deformation in the thickness direction, so the material is unable to thin down. As a result, elongation in one direction in the plane of the sheet can occur only if equal contraction is permitted in the perpendicular direction in the plane of the sheet; therefore, the 30 to 40% elongation measured in tension on what formerly had been thought to be optimum processed beryllium sheet, may have little or no value in its engineering use. This strongly directional ductility may be incapable of performing the essential engineering function that ductility normally performs.

Ductility, as measured by the plastic elongation just prior to fracture, is the property most in need of improvement to permit widespread beryllium usage in primary structures and power plants of a flight vehicle.

It is safe to assume that the minimum elongation expected of today's best aluminium alloys will suffice for future structures, and this elongation constitutes a valid indication of the ductility required of beryllium to become of general structural use. This permissible level is as low as 1% in extrusion and 1·5% in castings, but is no less than these amounts in any direction.

Tensile strength The ratio of density to ultimate tensile stress has been used to compare the weight of tension structural components made of various metals. These components, designed by tension criteria, abound in missiles and space craft and constitute by weight better than one-third of manned aircraft.

To find what ultimate tensile stress will be required of future beryllium to be competitive with aluminium, titanium, and steel, one must assume a value for the future ultimate tensile stress of these three conventional metals and multiply it by the ratio, density of beryllium: density of conventional material. The results of these calculations are given in Table III for various temperatures.

Compression Compression buckling criteria govern the design of better than half by weight of the structure of manned aircraft.

When comparing metals used in thin-walled structures designed by buckling criteria, one must distinguish between the various types of construction. For example, when considering sandwich-

TABLE II *Elevated-temperature tensile-test properties of beryllium*

Test temperature, °C.	Strain rate (in./in./min.)	U.T.S. (× 1,000 lb./sq. in.)	Yield strength (× 1,000 lb./sq. in.)	Reduction in area (%)	Elongation in ¼ in. (%)	Elongation in 2 in. (%)	Modulus (× 10⁶ lb./sq. in.)
540	0·005	22·4	19·4	7·2	12·7	4·1	37·1
650	0·005	12·5	12·5	2·3	5·5	1·6	31·6
730	0·005	7·7	7·7	1·5	9·1	1·9	17·9
820	0·005	3·1	3·1	2·5	13·2	3·2	5·8
900	0·005	1·3	1·3	7·9	20·4	9·5	3·5

type panels for low load-intensity structures, it may suffice as a first rough approximation to specify that the yield compression stress should be about 4/5 of the ultimate tensile stress listed above, to be competitive with the conventional metals.

The method used to obtain the relative weight of sheet-stringer panels at various temperatures gives the lowest yield compression stress required of beryllium.

Temperature, °C.	Intermediate load intensity (q/L_e = 200 lb./sq. in.)	High load intensity (q/L_e = 600 lb./sq. in.)
20	35,000	55,000
205	30,000	45,000
430	20,000	30,000
650	10,000	15,000

Comparing the data of the previous section with the properties of present beryllium, it can be seen that hot or warm extruded or warm rolled beryllium is the material of choice (stronger for equal weight) over the temperature range of 20 to 650°C. both in tension and compression. Hot pressed block is superior to aluminium, titanium, and steel only in the range of about 430 to 650°C.

The level of properties required for conventional construction (sheet-stringer, for example) is well known, and it is recognized that present commercial beryllium is inadequate for the purpose. These standard techniques have evolved because ductile materials were available. While the development of more ductile and stronger beryllium should be pushed, consideration should also be given to the possibility of a wider utilization of present beryllium by adjusting to its limitations.

A simple example can be cited. Beryllium bolts made with standard screw threads will fail readily in a brittle fashion. By changing the thread form to eliminate a sharp notch at the root, however, satisfactory beryllium bolts have been produced.

Working of beryllium

Present commercial beryllium is now produced from billets made by powder metallurgy procedures, from which all beryllium parts, sheet and rod, are fabricated. In the manufacture of powder metallurgy billets, the beryllium smelter product, vacuum-cast ingot, is first converted to chips by machining. The chips are ground to powder finer than 200 mesh, and the powder is then pressed at about 1,100°C. and in a vacuum of about 50 microns absolute pressure into what is known in the trade as vacuum hot pressed beryllium block. Large or intricate shapes are manufactured from the block by standard machining procedures. Such block usually serves as the starting material for extruded rod and bar and hot-rolled beryllium plate and sheet.

TABLE III *Comparison of tensile properties*

Temp., °C.	Conventional metal	Density (lb./cu.in.)	Future tensile stress assumed (lb./sq.in.)	Tensile stress required of future beryllium (lb./sq.in.)
20	Aluminium	0·10	100,000	70,000
205	Titanium	0·17	180,000	70,000
430	Titanium	0·17	130,000	52,000
			150,000	60,000
650	Steel	0·30	100,000	23,000
			120,000	27,500

At temperatures over about 760°C. pure beryllium oxidizes fairly rapidly, and therefore all hot-working operations, such as extrusion and hot rolling, require that the starting billet be protected from the air during hot-working operations. The standard method for accomplishing this is to encase the metal in a mild steel container. At the conclusion of hot working, the steel container is removed, most conveniently by dissolving it in 50% nitric acid.

Warm extrusion and warm rolling are carried out at temperatures below the oxidation temperature, and therefore no protective canning is required. Although warm extruded beryllium exhibits superior strength properties, the high extrusion pressure required has thus far limited the shapes produced to relatively small pieces of small cross-section. Bare warm rolling, while also giving improved physical properties and an excellent as-rolled finish, has not been practised extensively because of the difficulty of keeping the metal hot enough during rolling.

Beryllium, both hot and warm rolled, has demonstrated sufficient isotropic ductility between 485 and 595°C. to permit hot forming. In this temperature range the metal can be sheared and holes can be punched without difficulty. Successful sheet metal fabrication requires that the tools as well as the metal be maintained at the operating temperature throughout the forming operations, and, except for hole punching, the rate of bending or drawing must be relatively slow. The scale of demand for fabricated parts has been small until recently, therefore commercial practice closely resembles laboratory procedure.

The brittleness exhibited by beryllium at room temperature is much less in evidence at elevated temperatures. In spite of this, it is found that fabrication of beryllium at high temperatures is relatively difficult to carry out. Cracking of the metal during rolling or forging and, to a lesser extent, during extrusion, is apt to occur, and special precautions must be taken to avoid it.

Fabrication of aircraft components

Beryllium can be hot-formed (540 to 760°C.) into typical airframe shapes. It may be necessary to use heated tools to maintain the metal temperature. Cold forming (and cold straightening) should not be attempted.

The machining of beryllium can be accomplished to any desired degree of precision. The metal is dimensionally very stable. The only important limitations are the need for protecting the operator from the toxicity hazard and the desire to collect uncontaminated chips for re-use.

Joining The projected use of beryllium as a structural material makes it imperative that means be devised for joining beryllium to itself and to other metal components of an assembly. Conventional joining techniques have been investigated extensively, with promising results. Brazing has been found to be most satisfactory where it can be used.

Several properties of the metal lead to difficulty in welding and brazing: (1) Ease of oxidation at elevated temperature; (2) the low ductility of the metal; and (3) the high specific heat and the high heat of fusion, requiring a high power input for fusion welding.

A preliminary investigation has shown that, given suitable pretreatment, the adhesive bonding of beryllium is feasible. In this study, failures occurred in the metal at stresses ranging from 37,000 to 52,000 lb./sq. in.

Future research

The following are offered as topics to be considered in a research effort which has the objective of using beryllium in aircraft and missile airframes.

1. One of the more intriguing research prospects concerns a possible phase change in pure beryllium. Such a transformation (to an undetermined structure) has been reported, at a temperature only about 15° below the melting point. If this finding is confirmed, there would be strong interest in learning whether beta beryllium is ductile, and whether the phase could be retained to room temperature by alloying.

2. The solid solubility limits for oxygen, hydrogen, and nitrogen have apparently never been determined. The importance of this is in connection with purification attempts. Impairment of ductility, if any, is probably due to the gases in solid solution; gas content above this level is of secondary importance. The solubility level of gases in beryllium is apparently quite low; therefore any programme on purification should be accompanied by a refinement, or at least an assessment, of analytical techniques.

3. The question of whether oxygen-free metal will be ductile should be resolved. It might be very expensive to obtain a few grammes of pure metal, but, if this beryllium is truly ductile, attempts to deoxidize commercially can be started. The possibility that other gases are important to mechanical behaviour should not be ignored.

4. Since the ductility of beryllium is not great, the degree to which this is impaired by notches and surface imperfections should be studied. Such an investigation should include not only slow tensile elongation, but also complex stressing and rapid (impact) loading.

5. Accurate determinations of the solubility levels of zinc, cadmium, and lithium in beryllium would be of value, since these elements are of potential interest for alloying.

6. While improved ductility is strongly desired, there are applications for beryllium with its present ductility but with higher strength. Work has been reported in which copper additions have raised the strength without impairing ductility. This could well be followed up, using other alloying elements.

7. As is true with all metals, desirable mechanical properties of beryllium are associated with a fine grain size. Commercial beryllium is now a —200 mesh sintered powder product, this particle size being a compromise, because below this size the oxide content associated with the particle surface becomes excessive. If a finer grain size can be obtained, without at the same time adding objectionable amounts of oxygen, it would be expected that improved mechanical properties would result.

8. Such progress as has been obtained in improving the ductility of beryllium is a result of working the metal so as to cause a crystallographic alignment. Further improvement would be aided by a more detailed knowledge of matters, such as the critical resolved shear stress for slip and the manner in which fracture propagates. The ductility at elevated temperatures is quite satisfactory, but the variation of the mechanisms of slip and fracture as temperature is raised is not well understood. Several sets of slip planes must be active to permit grain rotation (without voids) in the production of textures. With better knowledge of the plastic properties of beryllium, it might be possible to predict and produce the optimum textures.

9. The presence of a ductile-brittle transition temperature for beryllium has not been established or disproved. Although usually associated with body-centred cubic metals (beryllium is hexagonal), the considerable increase in ductility with increased temperatures raises the possibility that there is a transition temperature for beryllium.

10. The possibility that beryllium could be processed in a fashion to maintain random crystal orientations and also contain a small amount of well-dispersed porosity, or of a dispersed, weak, and isotropic second phase should be looked into.

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Application research

1. Develop analytical techniques for impurities, especially for gases.

2. Develop beryllium-base alloys aiming for substantial ductility.

3. Determine practical maximum size and minimum gauge sheets, and practical limitations of joints.

4. Develop extrusion and sheet-forming techniques to get improved ductility and to reduce cost. Other fabricating processes should also be investigated with the same objective. Previous development has varied working and annealing schedules, with the preferred orientations obtained and the ductility values measured in a tensile test as the criterion. Similar experimentation should be carried out, using as the guiding mechanical test the bend ductility of a wide sheet. Thus, a new *optimum* processing may be found that provides sufficiently high ductility in the least ductile direction to permit relief of high local complex stresses without fracture.

5. Develop methods for making and keeping beryllium very fine grained after casting, extruding, rolling, etc.

6. Improve methods so as to reduce scrap loss and permit the economical re-utilization of scrap.

7. Among the additional property data required are strength and impact values at very low temperatures. A continuation of the collection of high temperature data is in order. Data corresponding to notched specimens covering all the usual properties are needed. Finally, all these data should be obtained on several of the more important grades of metal, such as flat-rolled sheet, cross-rolled sheet, and extrusions.

8. Work should be supported on the development of composite materials containing a substantial fraction of beryllium. It might be possible to utilize some of the peculiar properties of beryllium, perhaps sacrificing some other desirable attributes to obtain a structural element adequate to withstand the loading conditions of a particular application.

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Production of niobium and tantalum powders

NIOBIUM is best known as an alloy addition, in the form of ferrocolumbium, for stainless steels. One of the earliest metallurgical concerns to carry out research on the commercial production of pure niobium metal and powder was Murex Limited. Up to about 1954, supplies of the ore were extremely scarce and few metallurgists believed there was much object in seeking other uses for the metal. Some years ago, however, the research department of Murex investigated the production of pure niobium although there was no use for the metal at that time beyond a very limited application in electronics.

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The possibility of using niobium as a canning material for fuel elements was the main cause for the increased interest in it. In order to operate fast reactors without fear of failure it is necessary to have materials which can withstand with certainty the stress and corrosion at the high temperature obtained within the reactor. Several metals are capable of withstanding stress at high temperatures but for one reason or another they are not acceptable to reactor designers. Niobium is the most satisfactory metal for this purpose at the present stage of technological development of the metals concerned.

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In the dissolving section the first steps are taken in the complicated production process for turning out pure niobium. The niobium, tantalum and other metals, are extracted from the ore in the form of an aqueous solution which is fed to the separation section where the liquid-liquid process is operated. The metal separated from this section as pure salt is recovered and passed to the reduction section where it is reduced to a metal powder. This metal is not completely pure as it contains small amounts of oxygen, nitrogen, silicon and hydrogen. All of these

Sited to look into the reheating furnaces in No. 1 steel-strip mill at Stewarts & Lloyds Ltd., Corby, two Pye television cameras enable the operator to ensure alignment of the steel bars on the skids (Photo, courtesy Stewarts & Lloyds Ltd.)

Television in industry

F. D. GRIMMER

ALTHOUGH the television screen is a ubiquitous feature of life today, the potential applications of television in industry have by no means been exhausted. Improvements in design are constantly being sought in order to extend the field of application into industries with special requirements and working conditions. The following short review may perhaps be of service in showing some recent applications of current apparatus, developed by two leading British firms who exhibited recently at the Industrial Photographic and Television Exhibition at the Albert Hall, London. An excellent feature of this exhibition, incidentally, was that working television equipment was on show and available for operation by visitors. A Marconi Type BD871 camera was mounted in the roof of the building and surveyed the street below. The camera, fitted with remotely controlled focus, pan and tilt facilities, could be operated from the stand by visitors. Demonstrations of this kind do much to show how simple is the control and operation of a closed-circuit camera channel.

The closed-circuit installation

The basic form of an industrial television installation, such as the Marconi BD871, consists of a chain of three units linked by cables. These are the camera, control unit, and display unit or monitor. Some installations, *i.e.* the new Pye Mark IV, have a separate camera control panel for desk mounting, etc., thus making a chain of four units.

Most cameras for industrial television use a photo-conductive pick-up tube with the advantages of low cost and extreme compactness. Standard cameras now available are less than a foot in length by four or five inches diameter and are quite capable of feeding several monitors if desired. Monitor screens range in sizes from 5 in. to 27 in., measured diagonally. Remote camera control for lens changing and focusing is available and 'zoom' lenses make it possible to change from a wide-angle view to a close-up.

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Inaccessible viewing The classical method of seeing into inaccessible interiors is by optical techniques such as the periscope. These methods may be extended in application by the added use of television, thus enabling remote viewing for greater operator comfort and efficiency. A continuous scanning of the interior of steel furnaces has been achieved by BISRA using the combination of periscope and television camera. In many cases it is more convenient to view directly with the television camera, and various methods of protecting

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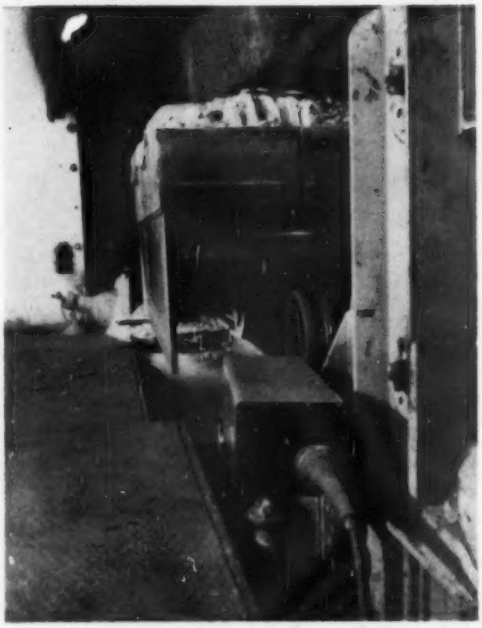
and cooling the camera are available where conditions at the site necessitate protective measures.

Television in steelworks

To give some idea of how the television chain is helping to ' extend the field of view ' of the operator of complex processes in the steel industry, recent installations in two large works may be briefly described.

One of these, at Colvilles Ltd., in Scotland, is in use at the pre-heating furnace to control the transfer of the ingots into the furnace. The ingots are loaded on to a number of bogies which run on a railway down the shop floor. The bogies are moved in a continuous line under the action of a go-getter. At one end of the railway, the bogies run on to a transfer car which moves at right-angles to the railway and brings the laden bogie opposite the doors at the charging end of the pre-heating furnace. The furnace at any instant contains 12 bogies in a line. At the discharge end a crane removes the ingots heated to 1,000°C. and carries them to the soaking pits where they remain until required by the rolling mills. Meanwhile, a second transfer car returns the empty bogie to the railway to be reloaded. When the furnace doors are opened to receive the laden bogie at the charge end, a powerful pusher rams the bogie from the transfer car into the furnace and one bogie emerges from the discharge end. The cycle of operations is initiated by the operator who is housed in a small cabin overlooking the discharge end of the furnace. Each bogie is loaded with approximately 30 tons of steel and the furnace handles about 3,000 tons of steel a week, running 24 hours a day in three shifts.



Before the cycle of operations can be initiated by the operator, he must be sure that the rails on which the bogie runs on the top of the transfer car are exactly in line with the rails which lead into the furnace. If this is not so, the action of the pusher will derail the bogie and it and its load will be forced into the furnace wall, causing considerable damage and a break in production. The alignment is achieved basically by means of limit switches, but the fine adjustment used to be under the control of an assistant who, when he was satisfied that the alignment was correct, signalled the ' go-ahead ' to the operator who then initiated the charging and discharging cycle.

The work of these assistants, one on each of the

1 ABOVE *Pye camera checking truck alignment at a preheat furnace at the Dalzell works of Colvilles Ltd. (Photo, courtesy Pye Ltd.)*

2 *Control room in the new rolling mill of the Steel Company of Wales fitted with 15 Marconi TV channels (Photo, courtesy Marconi Wireless Telegraph Co. Ltd.)*

three shifts a day, is now done by a standard Pye industrial television camera, housed in a dustproof case, 9 in. by 9 in. by 26 in., installed about 14 ft. away from the furnace door, and focused on the point where the two sets of rails meet, illuminated by a 1-kW. floodlight (fig. 1). The camera is connected to a monitor in the control box, and the camera control unit (located in the operator's box) is cooled by an air extractor fan.

Some years ago the Steel Company of Wales decided to replace the existing rolling mill at Port Talbot by a universal-type mill capable of rolling ingots at an increased rate. This in turn raised further problems. After the steel ingots are cast, they are brought to a uniform rolling temperature in the soaking pits *en route* to the rolling mill. The increased capacity after the installation of the universal mill meant that additional soaking pits were required and that the transport of ingots from the soaking pits to the mill had to be speeded up.

Under the old system an ingot was taken out of the soaking pits by a crane and placed on an ingot buggy which carried it to the rolling mill. In the new mill, however, this process was not fast enough to keep it running to capacity, so a new method was devised. An additional vehicle called the shuttle car now runs on the same track as the ingot buggy, operating between the buggy and the mill. First the buggy is positioned opposite a pair of soaking pits from which the ingots are to be drawn and the shuttle car is brought up to the buggy. A red-hot ingot is then placed in the buggy by a crane. The operator then upends the ingot on the buggy by remote control and runs it into the shuttle car by means of rollers. A second ingot is then placed in the buggy and the process repeated. The shuttle car then carries these two ingots to the mill and returns quickly to the buggy which may have been moved to another pair of soaking pits.

The shuttle car and the buggy are electrically controlled from a central dais or pulpit and the meeting of the two vehicles may occur at any point up to a distance of 1,000 ft. from the operator in the pulpit; nevertheless, it is essential for the operator to have a clear view of what is happening during these operations. The distance is too great for this to be done unaided and it was decided that the use of television would best overcome this problem.

In order to give a clear and accurate view showing every detail of the transfer of ingots, the viewing cameras must be at right-angles to the running track and to effect visual coverage of the several hundred feet of track over which the vehicles may meet, 15 cameras each with special wide-angle lenses were installed. These cameras are mounted in line with an outside wall of the rolling mill looking inwards and downwards at an angle through apertures at the relevant length of track. They are protected from the weather by canopies. The camera outputs are fed *via* cables to control racks in a basement of an adjacent building and thence to 15 monitors of new design which are installed in the operator's pulpit. The operator is thus presented with a composite picture of the whole length of track over which these two vehicles can meet (fig. 2). This is a good example of the application of the technique of 'simultaneous viewing.'

The installation posed several problems, notably those of the small amount of natural light available in the area and the high ambient temperatures (over 160°F.) which at times occur. The 15 camera channels are Marconi Type BD871 equipments, while the monitors are of new design.

Atomic energy applications

The field of application of television has recently been increased by the necessity of viewing the inside of constructions where a high level of radiation makes other methods difficult or impossible. Instances where the method has proved valuable are, for example, in cyclotrons and nuclear power stations.

The gas-cooled graphite-moderated reactor at Calder Hall was installed with a television camera developed by Pye Ltd. The design of equipment for use under such conditions raises many problems, and has to conform to very rigid specifications.

When it is desired to carry out an inspection of the reactor the pile is closed down by lowering the control rods into the graphite core. The coolant carbon dioxide gas continues to pass through the pile until the temperature has been reduced to about 200°C. At this stage the gas pressure inside the reactor is reduced to slightly above that of the outside atmosphere and the television equipment is wheeled into position close to a charging valve on the reactor cap. The posting box with the television camera inside is lowered over the selected valve and bolted firmly in position. After ensuring that no radioactive gas can escape, the valve is opened, giving access to the interior of the reactor, and the camera is lowered into position on a chute.

The camera may be operated with ambient temperatures up to 200°C., although the interior is maintained at the much lower temperature of approximately 50-60°C. This is achieved by cooling the camera with carbon dioxide gas supplied through the stainless-steel supporting hose from an external supply.

The optical system consists of a 1-in., $f1 \cdot 9$ lens with a horizontal viewing angle of 28 deg. Built-in lighting is provided by four 25-watt incandescent lamps grouped around the lens.

Non-ferrous metals research

Last month saw the opening by Sir Alexander Fleck of a new laboratory block at the headquarters of the British Non-Ferrous Metals Research Association. This is the first new laboratory block the association has been able to build since the war and with its completion most of the research work can go on in laboratories planned for the purpose instead of in improvised accommodation. The new building was made possible by a special voluntary contribution by members to an extension fund. The following article summarizes a few of the current research projects shown to visitors on the open days

1 *Alloying of newer metals, such as titanium, zirconium, and thorium, is carried out by melting in an arc furnace in an argon atmosphere. The one shown above was built by BNF when the technique was comparatively new*

THE MAIN FEATURES of the new BNF laboratory block are a much enlarged foundry, new corrosion and physics laboratories and a new electroplating shop, while alterations which have been made to existing buildings have enabled a new creep-testing laboratory to be built to take over 100 units, the former mechanical testing laboratory to be converted into a fatigue laboratory and more space to be allotted to apparatus for the determination of gases in metals. An important feature of the rearrangements is the creation of space where temporary equipment can be installed for specific projects as need arises.

Foundry work

The results of research work in the foundry show that even traditional materials like gunmetals can profit from research. The origin of the compositions used at present is lost in antiquity and a systematic study has made it clear that they can be improved. For certain purposes, particularly where thick sections are involved, none of the gunmetals in common use is ideal, the best all-round combination of good mechanical properties together with ease of casting being obtained from an alloy outside the present ranges specified.

To help in formulating sensible standards for gunmetals, the BNF is also making a detailed examination of the effect of the main impurities. Many foreign standards specify limits for a whole range of impurities, though there is little published evidence to suggest that they are harmful. Already the research has shown that sulphur, which is frequently limited in American and German standards for example, has no adverse effects even when present in quite large amounts; the influence of arsenic, antimony, bismuth and iron is now being investigated.

A new research has been started on the casting and properties of high-silicon aluminium-silicon alloys which have recently been attracting attention in the motor industry, and other work in progress is concerned with improving the resistance to stress corrosion of the high-strength cast aluminium alloys used in the aircraft industry.

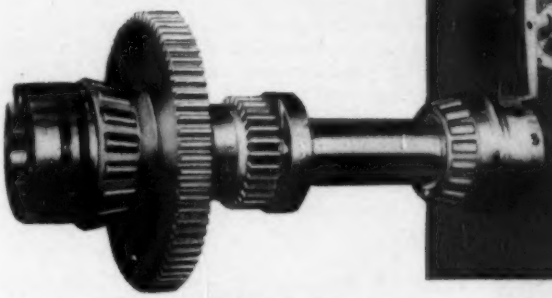
Structural use of aluminium alloys

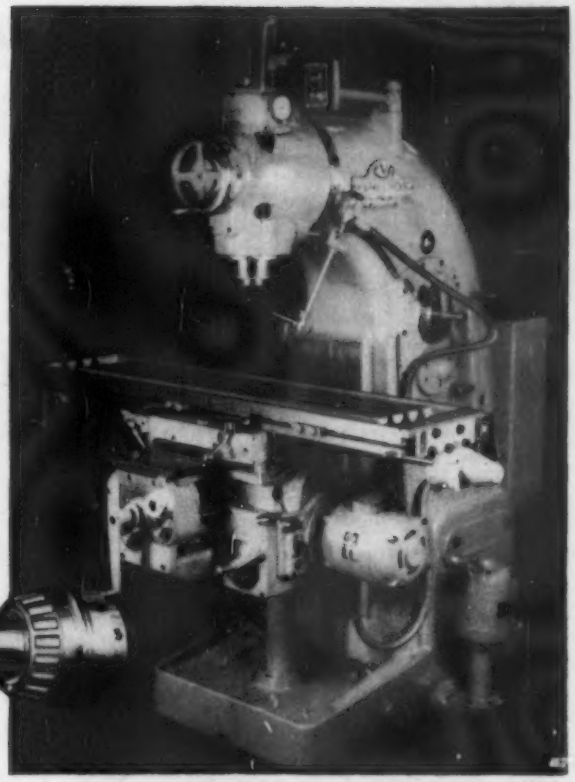
To help the designer make the best use of aluminium alloys for land transport applications, a detailed comparison is being made of the fatigue properties of medium-strength light alloys and structural steels normally used in the transport industry. Tests are going on not only with plain specimens but also with notched specimens, the results of which will influence joint design.

Two Vibraphore direct stressing fatigue machines,

NICKEL ALLOY STEELS

ensure reliability in machining





In the current designs of C.V.A. Jigs Moulds & Tools Ltd., Hove, who concentrate on high speed automatic and centre lathes, dieing presses and 'Milwaukee' milling machines, the constructional materials include various nickel alloy steels for the highly stressed components. The 1¼ per cent nickel-chromium-molybdenum steel, EN 24, one of the most useful compositions, is used for cams, shafts, spindles and other items which are either made from forged material or bar stock.

The reliability of C.V.A. automatics, now operating in thousands throughout the world, is a reflection of the reliability of nickel alloy steels under sustained stresses.

By utilising the better properties obtainable in more highly alloyed nickel steels, dimensions can be reduced, lighter constructions produced, distortion through heat treatment minimised and reliability and economy achieved.

TYPICAL MECHANICAL PROPERTIES OF

EN24

These steels exemplify its versatility both as regards strength and range of serviceable section sizes.

SIZE	HEAT TREATMENT	YIELD STRESS t.s.i.	MAXIMUM STRESS t.s.i.	ELONGATION per cent	IZOD ft. lb.
0·564" dia.	Oil quenched 830°C. tempered 200°C.	111·4	125·5	14·5	24
1½" dia.	Oil quenched 850° tempered 510°C.	79·5	83·6	15	28
1½" dia.	Oil quenched 850°C tempered 560°C.	68·3	73·5	19	55
2½" dia.	Oil quenched 840°C tempered 650°C.	57·3	64·1	20·5	65
5½" dia.	Oil quenched 830°C tempered 650°C	50·1	58·9	19·5	75

Send for 'The Mechanical Properties of Nickel Alloy Steels' ▶

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YGA 21/20

one of 10 tons capacity and the other of 2 tons capacity, are in use for this work in a new fatigue laboratory which contains several other varieties of fatigue machines for tests under bending stresses. Fretting fatigue in connection with aluminium alloys is also being investigated, the question being of great importance in the aircraft industry, and various anti-fretting agents are being compared.

A great deal of attention has been given to improving the transverse ductility of large high-strength aluminium alloy extrusions and forgings now used in aircraft. The research has mainly concerned DTD.683, the aluminium-copper-zinc-magnesium alloy which has a high proof stress. The low ductility sometimes encountered across the direction of working has meant that unusual care has had to be exercised in using large extrusions and forgings. An explanation for this low transverse ductility has been provided by research work, and recommendations for improving the position, among other things by modified forging techniques, are being tried out at the present time.

Improved production of copper alloys

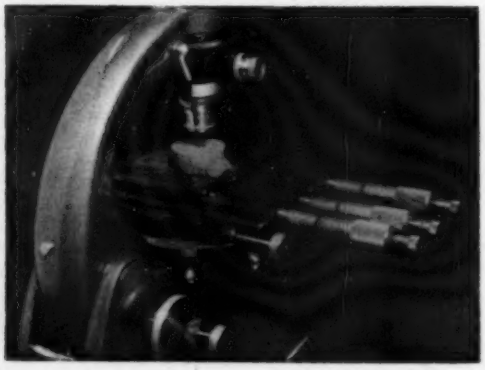
The prototype of a novel machine developed by the BNF for correcting strip for various rolling faults was demonstrated. This machine is designed to be placed between the working rolls of the mill and the coiler. It helps to correct such faults as 'waviness' and 'spoutiness' and, in addition, equalizes the internal stresses in the strip.

How much hydrogen is permissible in the atmosphere when bright annealing high conductivity copper and the reasons why adjacent turns sometimes stick together when bright annealing coils of wire or strip are being investigated. Although bright annealing has been in commercial use for many years, there is surprisingly little information about the permissible hydrogen contents of annealing atmospheres to avoid embrittlement of high conductivity copper at different temperatures. Similarly, the factors on which the tendency to sticking depend have never been looked into, although this is obviously a form of pressure welding.

Lead-clad steel

Lead has outstanding resistance to corrosion, particularly towards sulphuric acid and sulphur-containing fumes. However, it must be well supported as it tends to creep even under its own weight. A new BNF product, lead-clad steel, combines the corrosion resistance of lead with the structural stability of steel and should lead to increasing use of lead in the chemical plant industry where at present it is often applied by the costly process of hard burning. A method has been developed of rolling lead on to sheets of steel, and industrial trials have proved that it is possible to make lead claddings up to $\frac{1}{4}$ in. thick on large steel plates which can be welded together without difficulty. Several small articles made in this way were shown.

2 LEFT *The 500-ton press being used for extruding high-strength aluminium alloy strip in an investigation into its directional properties*



3 BELOW *This microscope stage is fitted with three micrometers to provide a simple means of determining the proportions of different phases in a specimen*

Another high-temperature problem solved by

NIMONIC ALLOYS

30-TON FORGINGS SUSPENDED FOR HEAT TREATMENT AT 1,000°C

A SPECIAL TYPE of 'cruet' for suspending forgings vertically during heat-treatment has been developed by William Beardmore and Company Limited. Weighing 4½ tons, it consists of two main members of heat-resisting steel, joined together by bolts 4 ft. long. These bolts must carry the weight both of the lower member and a forging of up to 30 tons, through a continuous heat-treatment cycle involving temperatures of over 1,000°C for 12-hour periods.

Under these exacting conditions, the axle-type steel bolts which were first employed quickly failed through scaling and lack of mechanical strength. A mixed set was then incorporated, consisting of four bolts of heat-resisting steel and four of NIMONIC 75. After a period of service, it was found that the steel bolts had extended and become virtually useless, and that the bolts of NIMONIC 75 alone were supporting almost the entire load. Because of this proved superiority, 3-in. diameter bolts of NIMONIC 75 secured to NIMONIC 75 nuts are now employed in all the 'cruets' used by Messrs. Beardmore for handling large forgings, with smaller bolts of the same material for forgings of up to 8 tons.

'NIMONIC' IS A REGISTERED TRADE MARK

WIGGIN NICKEL ALLOYS, *our technical journal, contains useful and interesting data on the application of Wiggin wrought nickel alloys. May we send you a specimen copy?*

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TGA HTA35

X-ray fluorescence analysis

Determination of the zinc content of brass in 1 minute with an accuracy at least as good as routine chemical analysis was demonstrated on an X-ray spectrometer. Research on the metallurgical uses of X-ray fluorescence analysis has been carried out for the past two years, using a spectrometer made in the workshop. The method is akin to spectrographic analysis, but instead of sparking the metal and examining the light spectrum produced, the metal is irradiated with a beam of X-rays and the X-ray fluorescence is split into a spectrum and analysed by means of a scintillation counter.

So far, the work has been confined to analysing brasses, tin bronzes and cupro-nickels, in all of which the main elements can be determined accurately, but it is soon to be extended to other metals and to ores.

The prototype of a commercial instrument, loaned to the BNF for evaluation, designed to carry out automatically complete analyses of alloys and record the results on a paper tape, was also shown.

Instrumentation

In the physics laboratory was shown a working model of an eddy-current instrument sorting brass tubes with manufacturing faults from good tubes. Automatic inspection of this kind is becoming more and more necessary with larger scale production and mechanization in the non-ferrous metals industry. Research is going on into several aspects of instrumentation. The one concerned with eddy-current testing is providing information about design of search coils for specific inspection problems, thus helping members to make the best use of available commercial instruments. The development of a satisfactory radiation pyrometer for measuring the temperature of aluminium alloys during hot working is the objective of another research. The low and variable emissivity of aluminium makes radiation pyrometry particularly difficult.

The BNF coatings gauge provides a completely non-destructive method of measuring nickel thicknesses on steel, brass or zinc alloy die-castings just by applying a probe to the surface. The immediate aim is to speed up readings, improve reproducibility and simplify calibration.

The newer metals

Much of the work on the newer metals is now connected with the nuclear-power industry, though research on titanium during the last ten years has provided a good deal of basic information on the types of alloys from which creep resistance coupled with good forgeability can be expected. One laboratory is set aside for an investigation into the metallurgy of thorium and its alloys, the object being to produce thorium-based materials having adequate strength at high temperatures to be used as nuclear-power fuel elements. In its unalloyed form thorium is insufficiently strong at the operating temperatures of a reactor, but some promising high-strength materials have been developed and their creep properties are being evaluated. Special creep-testing equipment has had to be developed to enable the testing to be carried out in purified argon since thorium is too reactive to test at high temperatures in air.

Another research is concerned with the development of high-strength zirconium alloys which are of interest as canning materials for nuclear fuel elements, and the same type of creep-testing equipment is being used. Work is also commencing on certain aspects of the metallurgy of the production of uranium fuel elements.

Radioisotopes

Compounds labelled with radioactive tracers are proving most useful in fundamental work designed ultimately to improve nickel-plating solutions. It is known that the complex organic substances added to modern nickel-plating solutions to give the deposit such qualities as smoothness and brightness while retaining reasonable ductility, become incorporated in the nickel to some extent, though the amounts involved are too small for ordinary chemical analysis. With typical addition agents specially prepared by the Radio Chemical Centre with a radioactive isotope such as carbon C_{14} or sulphur S_{35} as tracer, the extent of incorporation of the organic agents can be determined by checking the deposits with a Geiger counter.

High-temperature brazing

Brazing of high-temperature alloys such as Nimonics is being studied. Such alloys are more difficult to braze than normal materials since they invariably have refractory oxide films which hinder the wetting of the surface by the brazing metal. Furthermore, the conditions in which they are used are more arduous than normal components have to withstand, so that soundness of the joint is of the utmost importance. The work covers fundamental aspects such as joint design and method of heating necessary to ensure complete soundness of joints, the correct combinations of brazing metal and basis metal for different circumstances and the high-temperature strength of the joints. High-temperature brazing is now coming into industrial use and could do much to cheapen, for example, the production of gas turbine parts where at the moment much of the assembly has to be carried out by high precision-machined joints. Work on brazing titanium alloys where similar problems are encountered has just started.

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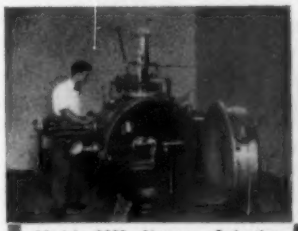
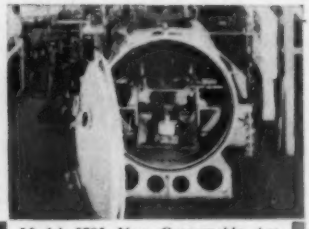


Model 2555 Vacuum Induction Furnace with melting capacity of 50 pounds of steel. Other standard furnaces have capacities of 12 to 3,000 pounds.



Model 2705 Non-Cunsumable Arc Skull Furnace with a capacity of 50 pounds of titanium. Other standard vacuum arc furnaces have capacities of 8 to 10,000 pounds of titanium.

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New controlled atmosphere furnace

Discharge end of G.W.B. electric roller-hearth furnace

EARLE, BOURNE AND CO. LTD., Birmingham, a member of the Delta Group, have long been well known as manufacturers of copper and copper alloy sheet, tubes and sections. A remodernization programme has recently been carried out which included the installation of an electrically heated driven roller-hearth furnace supplied by G.W.B. Furnaces Ltd., for the annealing of copper and brass tubes. This unit has replaced a fuel-fired furnace which was used for annealing, after which the tubes had to be pickled in an acid bath to provide the bright finish normally required. Since the G.W.B. furnace operates under a protective atmosphere provided from an exothermic burnt town's gas plant, also supplied by G.W.B., the pickling process has been eliminated since the tubes now emerge from the discharge end quite bright in the case of copper tubes and clean in the case of brass tubes.

The furnace is heated by electric resistance elements situated in the roof of the heating chamber, and in the hearth beneath the driven rollers. A maximum rating of 285 kW. is provided, spread equally over the three-phase supply, and for control purposes, this rating is divided into three zones arranged longitudinally along the furnace.

The complete installation is nearly 150 ft. long, which includes a loading table 35 ft. long and an unloading table 40 ft. long. The most common charge consists of copper tubes in lengths up to a maximum of 35 ft. and with a diameter range from ½ to 4 in. o.d. This length is the maximum which can be catered for in straight form, and beyond this the tubes are coiled on a bull-block up to a maximum length of 60 ft. forming coils 5 ft. 6 in. diameter which are also passed through the furnace. The unit has basically been designed for an output of 2 tons/h. of annealed tube, although this naturally varies with the particular charge characteristics. The average hourly throughput at the present time is 39 cwt. when in lengths and 35 cwt. when coiled.

The G.W.B. protective atmosphere plant consists of three combustion chambers in which a carefully determined mixture of town's gas and air is burned in a ratio of approximately 2½/3 : 1. The partially burned product is passed through a water-sprayed coke-filled 'scrubber' box for cleaning and cooling, and then through purifying units containing bog-ore and activated carbon to reduce the sulphur content as far as possible.

All rollers are of mild steel except where they are situated in the actual furnace itself and in the first portion of the cooling chamber, in which case they are of drawn heat-resisting material. Arrangements are made for easy withdrawal of the tubes from the side of the furnace should this be necessary, without having to shut down the drive for the whole installation.

The 44-ft. long cooling chamber is water-jacketed, and effectively reduces the temperature of the charge coming from the furnace so that it can be handled on discharge, and it emerges into normal atmosphere well below the point at which oxidation might take place.

Each of the three heating zones is controlled independently and automatically by an Electroflo electronic indicating controller, while a three-point recording instrument gives a permanent indication of thermal conditions along the length of the furnace.

Effect of die shape in extrusion

THE SHAPE AND SURFACE FINISH of the die affect the dimensional accuracy and surface quality of an extruded product. The extrusion of products of non-symmetrical section calls for much skill and experience since, among other things, it is necessary to ensure a balanced flow of metal through all parts of the die. The resistance to flow is greater in the narrow parts of the die and if this is not allowed for correctly the product will be buckled or twisted.

The results of the first stage of an investigation of the effects of the shape of the die on the flow of metal during extrusion are now available. It is hoped that this work may eventually lead to a more rational understanding of the extrusion of non-symmetrical sections. The flow of metal can be modified by altering the shape of the die entry to obtain the required frictional conditions, and by altering the position of the die aperture relative to the axis of the billet being extruded.

It is also necessary to balance the flow of metal when extruding several sections simultaneously through a multi-aperture die, and this has been investigated as a preliminary to studying the flow through single apertures of non-symmetrical section. With a multi-aperture die balanced flow of metal is obtained when the velocity of each product as it leaves the die aperture is the same. When extruding simultaneously through two apertures of different size, balanced flow is obtained only if the centroid of the apertures is displaced from the axis of the billet. Tests on non-ferrous metals have shown that the conditions under which the initial and final parts of the product are extruded always lead to twisting and bending.

Further information about these preliminary results is given in MERL Plasticity Report No. 127, available from the Mechanical Engineering Research Laboratory, East Kilbride, Glasgow.

Melting reactive metals

Explosion risks in plants melting zirconium and similar reactive metals can be reduced by using air-cooled moulds to catch the molten metal, the Bureau of Mines, U.S. Department of the Interior, has reported. Researchers at the Bureau's Albany, Oreg., Metallurgical Research Centre, have recently concluded experiments with several moulds, or crucibles, of different designs, all cooled with air.

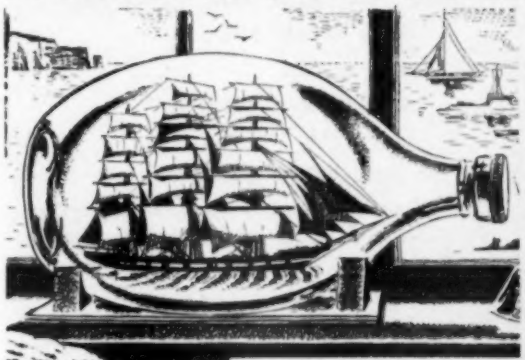
Zirconium is one of several new metals that require care in melting. This may also be said for such metals as titanium, columbium, tantalum, and hafnium. Severe blasts have occurred when these metals were arc-melted into water-cooled moulds, probably because water, normally circulated between the outside of the mould and a jacket surrounding it, contacted molten metal when the mould was accidentally burned through. The hot metal, sometimes reaching temperatures as high as 5,440°F., makes the water break up into molecules of oxygen and hydrogen, which recombine, producing an explosion.

The Bureau's report describes in detail how the air-cooled moulds were designed, fabricated, and tested at the Albany centre. Most of the vessels were copper; stainless steel and aluminium proved unsatisfactory. The best model, which could be cooled up to 35% more efficiently than a water-jacketed type, had projecting fins which provided more surface to the cooling air.

Although one air-cooled model was burned through during testing and molten metal contacted the cooling air, no explosion resulted and damage was confined to the mould.

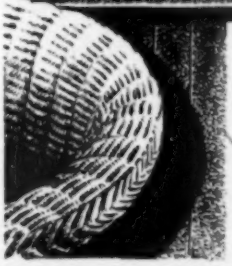
A copy of Report of Investigations 5443, 'Air-cooled crucibles for cold-mould arc melting', can be obtained from the Bureau of Mines, Publications-Distribution Section, 4800 Forbes Avenue, Pittsburgh 13, Pa. Requests should refer to the report by number and title.

MORE IDEAS BEGIN WITH BORON



But now the glass goes into the boat

The well-known toughness of glasses such as ovenware, laboratory glasses and other specialised types, is largely due to the presence of boric oxide. This product is also an important constituent of the tough, borosilicate fibres which are now creating a new and completely different future for glass. These strong glass fibres are moulded with plastics into sturdy, lightweight structures for modern boat-building, woven into textiles for electrical insulation or made into 'blankets' to insulate a house. This contribution to a rapidly-expanding industry is yet another use for boron and boron compounds. In nuclear research, in rocket fuels, in new synthetic materials, as well as in established fields of industry and pharmacy, their varied properties give rise to many new possibilities for progress.



BORON IN VITREOUS ENAMELLING

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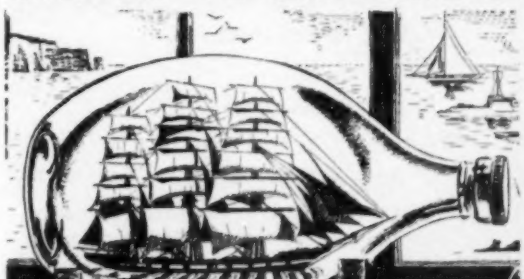
A copy of Report of Investigations 5443, 'Air-cooled crucibles for cold-mould arc melting', can be obtained from the Bureau of Mines, Publications-Distribution Section, 4800 Forbes Avenue, Pittsburgh 13, Pa. Requests should refer to the report by number and title.

MORE IDEAS BEGIN WITH BORON



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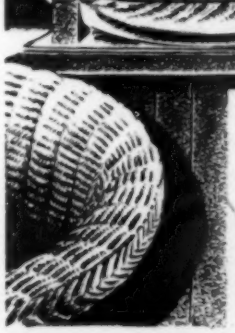

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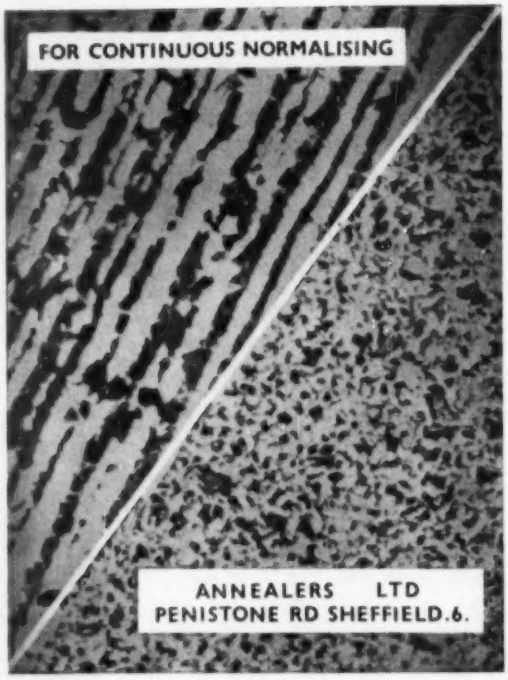

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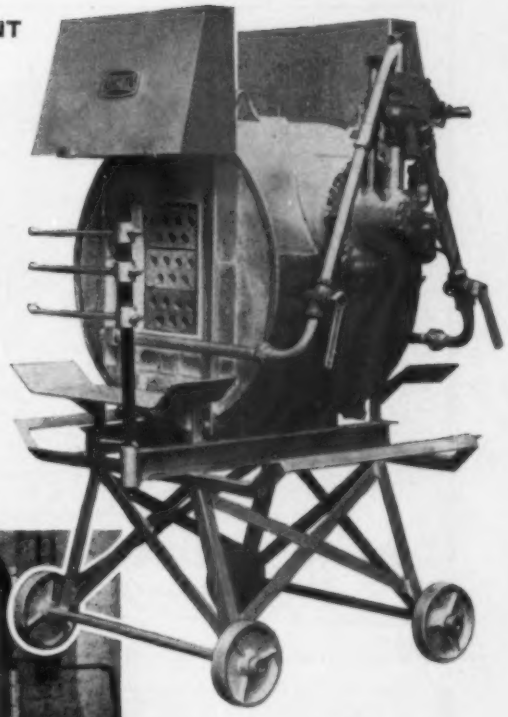

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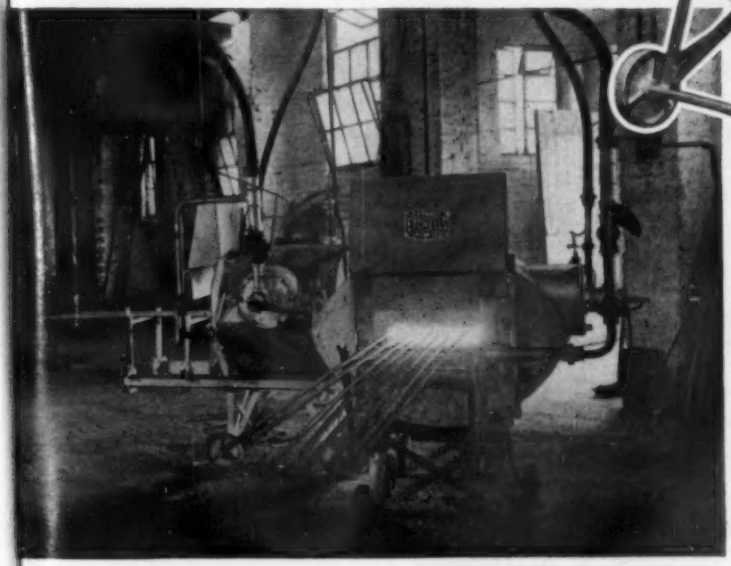

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INDEX TO ADVERTISERS

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Alldays & Onions Ltd.	—
Andrews, Thos., & Co. Ltd.	32
Annealers Ltd.	30
Birlec Ltd.	—
Birlec-Efco (Melting) Ltd.	—
Borax Consolidated Ltd.	27
Brayshaw Furnaces & Tools Ltd.	—
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Ether Ltd.	6
Eumuco (England) Ltd.	11
Fel Electric Ltd.	—
Firth-Derihon Stampings Ltd.	14
Flame Hardeners Ltd.	32
Fuel Furnaces Ltd.	—
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Gas Council	—
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General Refractories Ltd.	—
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Gibbons (Dudley) Ltd.	—
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G.W.B. Furnaces Ltd.	17
Hadfields Ltd.	—
Head Wrightson Machine Co. Ltd.	—
Hedin Ltd.	30
Herbert, A., Ltd.	—
Honeywell Controls Ltd.	—
I.C.I. Ltd.	1 & 13
Incandescent Heat Co. Ltd. (The)	4
Integra, Leeds & Northrup Ltd.	—
Johnson Foster, H., Ltd.	34
Kelvin & Hughes (Industrial) Ltd.	—
Kiveton Park Steel and Wire Works Ltd.	—
Lafarge Aluminous Cement Co. Ltd.	15
Letchworth Heat Treatment and Hardening Co. Ltd.	32
Manchester Furnaces Ltd.	—
Massey, B. & S., Ltd.	2
Mellowes & Co. Ltd.	33
Metalectric Furnaces Ltd.	29
Modern Furnaces & Stoves Ltd.	18
Mond Nickel Co. Ltd.	21
Morgan Refractories Ltd.	12
Morris, B. O., Ltd.	10
Nash & Thompson Ltd.	33
Newall, A. P., & Co. Ltd.	—
Nitralloy Ltd.	—
Nu-Way Heating Plants Ltd.	—
Peart, E., & Co. (Electronics) Ltd.	16
Priest Furnaces Ltd.	—
Sawbridge & Co.	30
Selas Gas & Engineering Co. Ltd.	—
Shell-Mex & B.P. Ltd.	—
Siemens-Schuckert (G.B.) Ltd.	—
Sifam Electrical Instrument Co. Ltd.	—
Smethwick Drop Forgings Ltd.	5
Somers, Walter, Ltd.	36
Spear & Jackson Co. Ltd.	—
Special Steel Co. Ltd.	—
Stein, John G., & Co. Ltd.	—
Thermic Equipment & Engineering Co. Ltd.	35
Thompson, Joseph, (Sheffield) Ltd.	—
Thompson L'Hospied & Co. Ltd.	9
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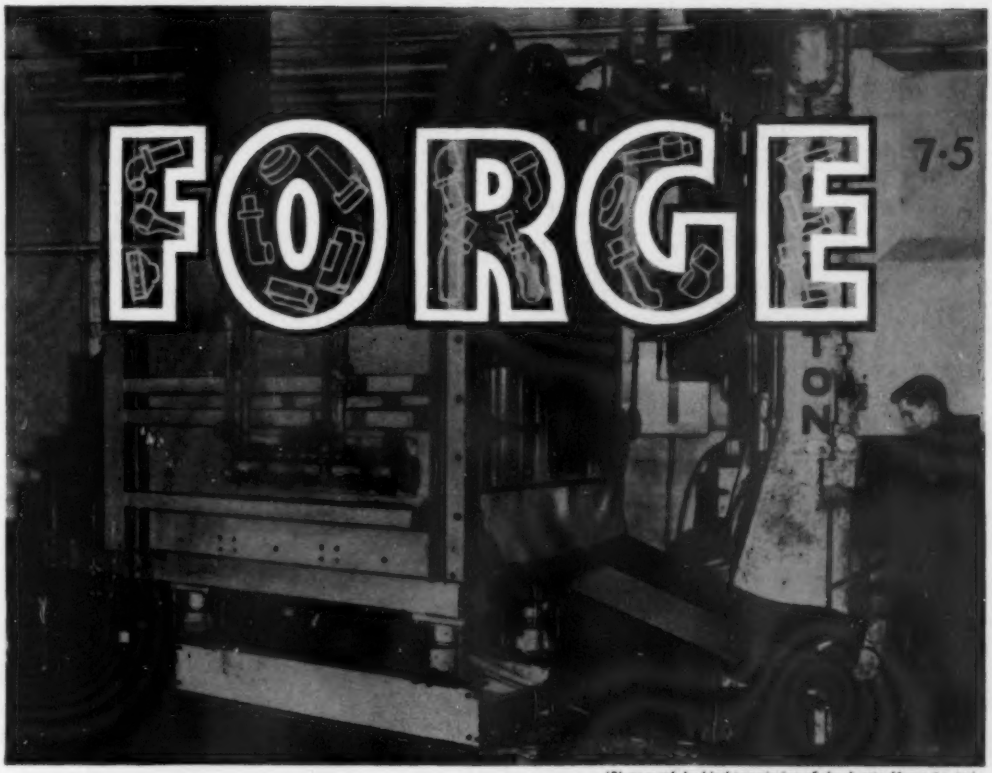

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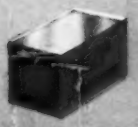

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